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IMPROVING THE STATISTICAL RELIABILITY OF STREAM HEAT ASSIMILATION PREDICTION

Richard W. McLay

PREPARED FOR
National Environmental Research Center

June 1975

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This work is an evaluation of existing, one-dimensional stream temperature prediction techniques for accuracy and precision. A sensitivity analysis of a general model is used in conjunction with statistical methods to determine solution errors. Data taken in 1973 at the Vernon, Vermont nuclear plant are used as a data base. These data are used with Burlington, Vermont airport weather station data to 1) gain insight into the orders-of-magnitude of the various errors and 2) carry out a detailed data analysis to establish probabilities of meeting given error requirements.

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IMPROVING THE STATISTICAL RELIABILITY OF STREAM HEAT ASSIMILATION PREDICTION

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ABSTRACT

In response to an increased interest in water quality by the public, a large effort has been mounted to develop mathematical models for predicting heat assimilation in bodies of water. The accuracy of these models has recently come under scrutiny due to the need for temperature predictions within 1 ^{o}C of the ambient. This work is an evaluation of existing, one-dimensional stream temperature prediction techniques for accuracy and precision. The approach is through error estimates on a general model that encompasses all of the models presently used. A sensitivity analysis of this general model is used in conjunction with statistical methods to determine the solution errors. Data taken in 1973 at the Vernon, Vermont nuclear plant are used as a data base. These data are used in conjunction with Burlington, Vermont airport weather station data to 1) gain insight into the orders-of-magnitude of the various errors and 2) carry out a detailed data analysis to establish the probabilities of meeting given error requirements. This report contains the model descriptions for the general stream model, the sensitivity analysis model, and the data analysis models; a description of the Vernon, Vermont site; the data for four problems from the Vernon nuclear plant; an order-of-magnitude error study; and the results of the four data analyses. The four appendices contain 1) a description of the input FORMAT specifications, 2) the input data for the four problems, 3) program listings, and 4) the theory of the sensitivity analysis.

This report was submitted in fulfillment of Contract 68-03-0439 by Richard W. McLay, P.E., Essex Junction, Vermont, under the partial sponsorship of the Environmental Protection Agency. Work was completed as of May 1975.

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SECTION I

CONCLUSIONS

1. One-dimensional stream temperature models are effective for predicting average temperatures over a short period of time.

2. Predictions made using site data averaged over a day will be within 2 ^{o}F (1.11 ^{o}C) of the actual average temperature of the following day over 90 percent of the time.

3. The water temperature at the Vernon site is the most important factor in the analysis. The Vernon study indicates that meteorological factors affect the Connecticut river predictions results very little. Travel time thus appears to be a major factor since a knowledge of the initial temperature is essential to accurate predictions.

4. Seasonal effects on prediction accuracy are minor.

SECTION II

RECOMMENDATIONS

The results of this study indicate that, in this case, water temperature at the site is the most important variable in the prediction of the downstream Connecticut river temperature. In order to minimize the errors of prediction, it is recommended that temperatures be monitored upstream of the site and predictions be made over as short a period of time as possible, i.e., average the previous day's data to predict the following day's average temperature. This is motivated by the need to know the initial temperature in the analysis for the entire travel time of water through that portion of the stream being simulated.

These predictions are useful to a plant operator making day-to-day decisions as opposed to a planner predicting conditions to occur several years in the future using an historical weather data base.

This work indicates that for the Vernon plant such predictions will have error within 2 ^{o}F (1.11 ^{o}C) 90 percent of the time. Smaller streams may have greater effects from meteorological parameters, which were not found from the Vernon problems. It is also recommended that similar sensitivity analyses be performed for two-dimensional models used for predicting temperatures in lakes, estuaries, and cooling ponds.

SECTION III

INTRODUCTION

PURPOSE

Stream temperature is an important factor in water quality. The temperature of the stream directly controls the types and amounts of plant and animal life native to it. In recent years there has been an increased interest in water quality by the public. In response to this interest a very large effort has been mounted to develop mathematical models for predicting heat assimilation in bodies of water.

Models have been developed for predicting temperatures in streams, cooling ponds, reservoirs, estuaries, and large lakes (See, for example, the review by Policastro and Tokar [1972]). Usually, a stream model assumes a one-dimensional problem with uniform mixing and with various modes of heat transport at the air-water interface simulated by semi-emperical expressions. In addition, the problem is generally treated as one in a steady-state condition, i.e., the formulation involves a relationship between the flow rate and the position downstream from an initial point, x, allowing the independent variable to be chosen as the variable x while the time variable becomes implicit to the problem. While the development of stream models is straight-forward, their use is subject to a great deal of interpretation and judgement (See, for example, Asbury [1970]).

The purpose of this study is to determine the effects of variations in initial temperature and meteorological data on results of mathematical models for predicting stream temperatures.

SCOPE

Three principal problems inherent in model use to predict heat assimulation are:

1. The extrapolation of weather station meteorological data to the site under study is subject to considerable variance.

2. There is usually a lack of data from which to compute the evaporation and other heat transfer rates for a stream.

3. The temporal variations of the data cause large variations in short-term predictions.

In addition to these, we find that the spatial and temporal variations of temperature in the environment without the addition of a heat load may be greater than either the requirements set by a regulatory agency or the errors inherent in the model, i.e., there is a question as to what the ambient values really are. Local variations in topography and/or tree cover can shade the stream and cause effective incoming and outgoing radiation areas to be reduced. The accuracy of instruments used to measure the various physical quantities is always subject to review. Ground water advection can be an influential transport process, but it is almost impossible to measure. Finally, the large amount of data taken for any site provides a good probability for human error in recording or transposition.

This study considered the three principal problems listed above by using a sensitivity analysis of a general, one-dimensional stream model. This was combined with data analysis techniques to compute the probabilities of meeting given error requirements. Data from the Vernon, Vermont nuclear plant and the Burlington, Vermont weather station were used to form a data base, from which four example problems were obtained and evaluated.

SECTION IV

MODEL DESCRIPTIONS

THE GENERAL STREAM MODEL

The stream model used for the study is one-dimensional with the independent variable being the distance downstream, x. This model is simple enough that a general version of it can be considered that encompasses all one-dimensional models now in existence. A discussion of this concept is given in Appendix D.

All one-dimensional models take a basic form as shown in Figure 1 and are described by the equation:

$$\frac{uA}{\ell}\frac{dT}{dx} = [Q_{Rad} - Q_{Ref} - Q_{Back} - Q_{Evap} - Q_{Conv} + Q_{Mis}] \quad (1)$$

where the variables are as defined in Section VIII, Symbols and Variable Names, and the water is fully mixed at each cross section. Any departure from the form of equation (1) due to direct integration, approximations to the heat fluxes Q, etc., can be shown by a Taylor's expansion to be proportional to some power of the mesh size. (See Appendix D). Put simply, as the number of stations or data points in the models are increased they will all produce results converging toward the same solution, provided that total heat fluxes and the heat transfer coefficients are the same. The fundamental heat flux expressions used in this work are taken from Laevastu [1960], where the processes are linearized in T. Not all authors use linearized expressions (See for example Jaske [1971]). However, numerical experience shows that if the temperature variations are small, i.e., small with respect to absolute temperatures, and of course they always will be, it is justified to linearize the expressions, including the fourth power terms in the back radiation fluxes.

The concept of using a simple, general model was considered essential in this work, since it reduced the study from a huge data handling problem for many models to the study of a single, general model whose error analysis applies equally well to all models in question, provided a convergent mesh size (station length) is specified.

The expressions for the heat fluxes from Laevastu [1960] are:

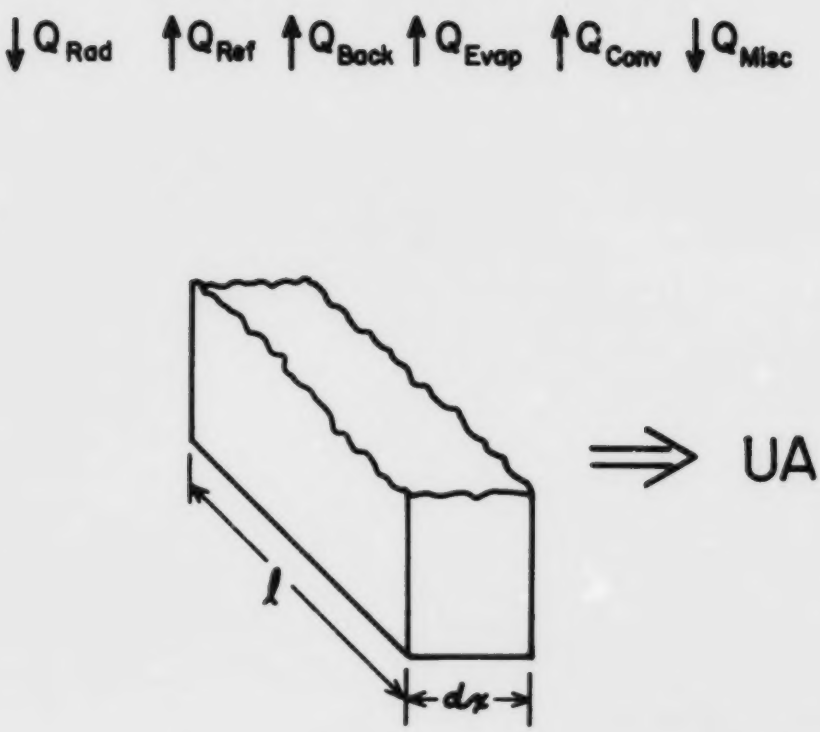

Figure 1. Control volume for stream model

$$Q_{Solar} = 1.9 \sin \bar{\alpha} \, (1 - 0.0006 \, C^3)(0.061) \quad ,$$

$$Q_{Reflected} = \frac{3}{\bar{\alpha}} \, Q_{Solar} \, (0.061) \quad ,$$

$$Q_{Back} = (1.0 - 0.765 \, C)(14.38 - 0.09 \, (\tfrac{5}{9} \, (T - 32) - 0.046\phi)(\tfrac{1}{69.72}) \quad ,$$

$$Q_{Evaporation} = \frac{\rho \, h_{fg}}{240} \, (0.35)(1.0 + 9.8 \times 10^{-3} \, W_2)(e_W - e_a) \quad ,$$

$$Q_{Convection} = 39.0(T - T_a)(0.26 + 0.077 \, W_2) \, \tfrac{5}{9} \, (0.061) \quad . \qquad (2)$$

The definitions are given in Section VIII. It should be noted here that the coefficients from these terms are largely based on empirical data and in many cases will vary considerably. However, as is seen in Section VI, the sensitivity analysis reveals little change in temperature decay rates with considerable change in these flux expressions for the Connecticut River. For smaller streams, this would not be the case.

THE SENSITIVITY ANALYSIS MODEL

In order to study the errors in stream temperature produced by the errors in input data, it is necessary to develop certain error expressions from equation (1). These are developed in view of the two fundamental definitions from Rosko [1972]:

1. Accuracy is defined as conformity of fact.

2. Precision is defined as sharpness of definition.

In the case of this work then, accuracy refers to the convergence of the solution to the actual stream temperature. Similarly, precision refers to the rate of convergence.

The sensitivity, or error, analysis required for the work was developed from equation (1) by making a small change, or variation, in the variables. Equation (1) can be rewritten symbolically as

$$\frac{dT}{dx} = \frac{\ell}{Au} \, Q \quad . \qquad (3)$$

A variation of both sides of this equation yields

$$\frac{d\,\delta T}{dx} = \frac{\ell}{Au}\,\delta Q \quad , \tag{4}$$

where it is assumed that the flow rate and stream width are known and that the process described is linear in its variation. If the error in temperature, $\delta T(o)$, is known at the initial point, it is apparent that, given the errors in the heat fluxes, δQ , the error at any given point downstream can be computed from equation (4) by a direct computation.

It is important to note that, if approximate values of the coefficients in equation (4) are obtained as constants, the equation can be solved in closed-form,

$$\delta T = A \exp[-\alpha x] + \sum_i C_i \quad .$$

Results of an analysis of this type are presented in Section VI.

THE DATA ANALYSIS MODELS

Previous sections have described the mathematical model studied and the sensitivity analysis model. The first of these models, or close variations of it, has been used extensively to predict the mean temperatures of streams. The sensitivity analysis model has the capability of predicting the error in the mean temperature at a point downstream, given the corresponding errors in the mean initial condition for temperature and the mean meteorological conditions. Thus, the mathematical models were available for a study, setting the stage for the data analysis.

The philosophy of the data analysis emerged from the concepts of probability. As has been shown by Hogan et al. [1972], it is unrealistic to establish the error in the estimate of the mean temperature deterministically. Rather, the statement must read to the effect:

> If the errors in the heat fluxes $|\delta Q|$ and the error in initial mean temperature $|\delta T(o)|$ are constrained in size to given values, then the probability that the error in mean stream temperature $|\delta T| \leq 1/n\ ^{o}C$ will be P_1 , $|\delta T| \leq 1\ ^{o}C$ will be $P_2 (P_2 > P_1)$.

Put simply, for given errors in the initial mean temperature and the meteorological data, it is possible to determine the probability of meeting a given error requirement. This can be done by using the sensitivity analysis model, which appears to be a very realistic approach to assessing the effects of the introduction of a heat load.

The methods employed in the data analysis are best visualized by using Figure 2, where the six primary variables are illustrated. The effect of errors in these variables is shown schematically in the figure, where the initial error δT is seen to decrease with increasing x. By collecting a data base of these variables over a period of several months, it was possible to make use of the sensitivity analysis to compute the error in temperature for a number of trials, based on moving averages. With an increasing number of trials the probability, P, that $|\delta T|$ is less than some given error in temperature can be estimated from:

$$P \doteq \frac{\text{Number of trials with } |\delta T| < \text{given value}}{\text{Total number of trials}} \quad . \quad (5)$$

Figures 3 and 4 illustrate the methods for utilizing the data base to evaluate equation (5). Figure 3 shows schematically the data base at an airport weather station remote to the site, in this case the Burlington, Vermont weather station. These data are collected together with the stream temperatures at the site every three hours, eight points per variable per day. These data are averaged over a specified number of previous days, then compared with the respective averages over the day following to form the errors in the input variables, $\delta\phi$, etc. The sensitivity analysis is then used to predict the errors in temperature downstream. These are then compared with the given temperature error requirement and the components of equation (5) computed. It should be noted here that this model simulates the errors of an observer at the site attempting to predict the temperature several days ahead.

Figure 4 shows schematically the second data analysis model, where the data base includes 1) the remote weather station data, 2) the stream temperatures at the site, and 3) the average daily stream temperature above the site (See Figure 5, station 7). In this case the daily average of the station 7 temperature is compared with the following day's daily average temperature at the site. Meteorological data are averaged in an analogous manner, i.e., daily averages compared for two consecutive days. These form the errors in the input variables. The sensitivity analysis is then used to predict the errors in temperature downstream, these are compared with the given temperature error requirements, and the components of equation (5) computed. This

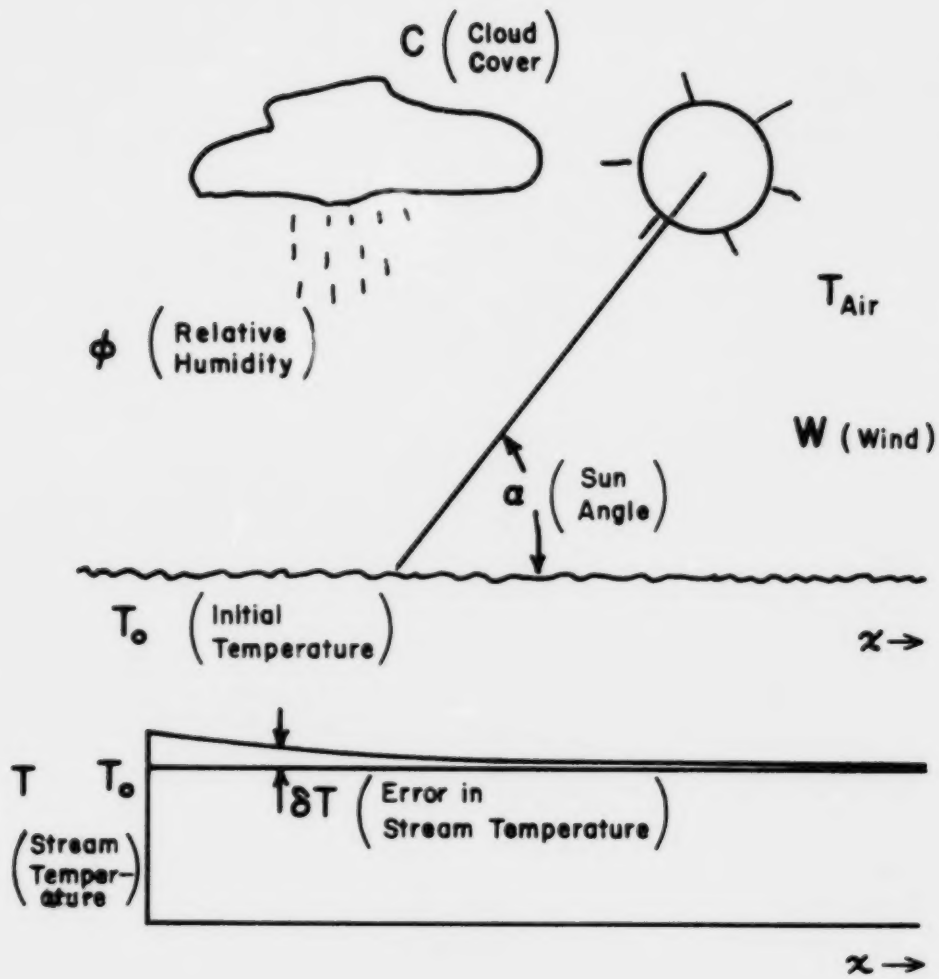

Figure 2. Six primary meteorological and site variables

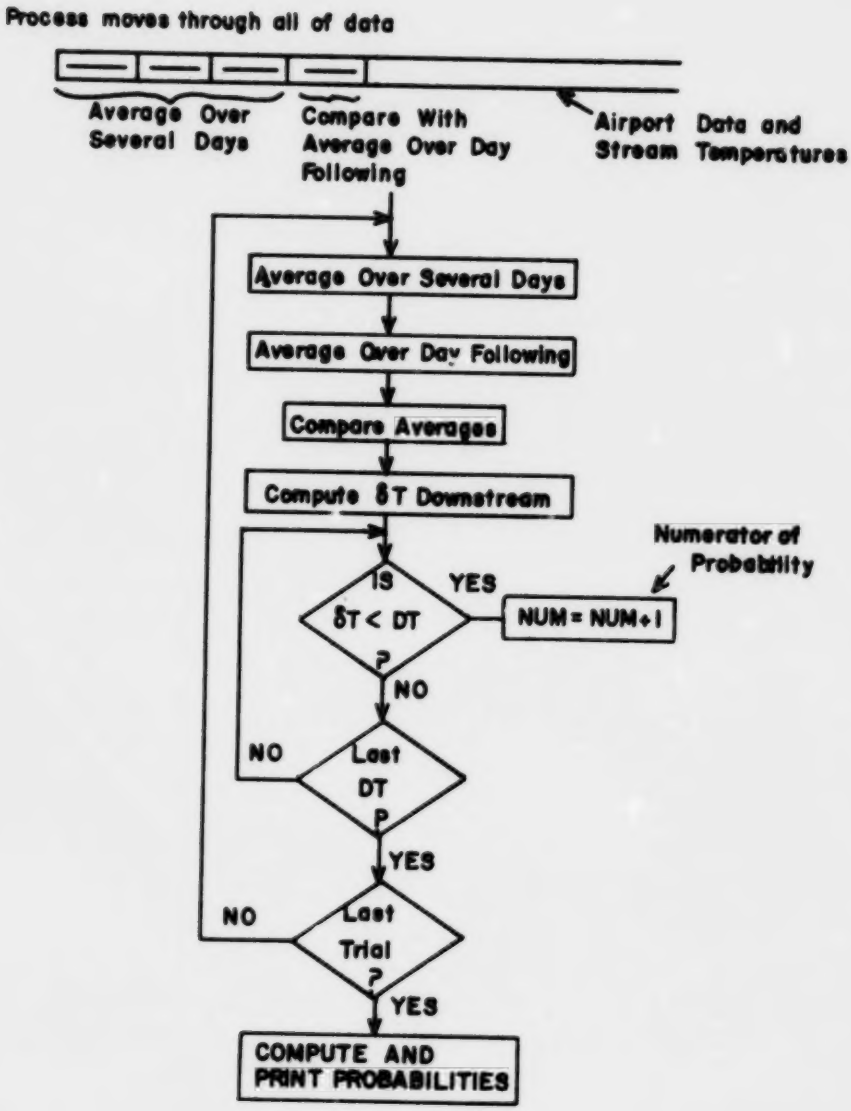

Figure 3. Model using site water temperature data

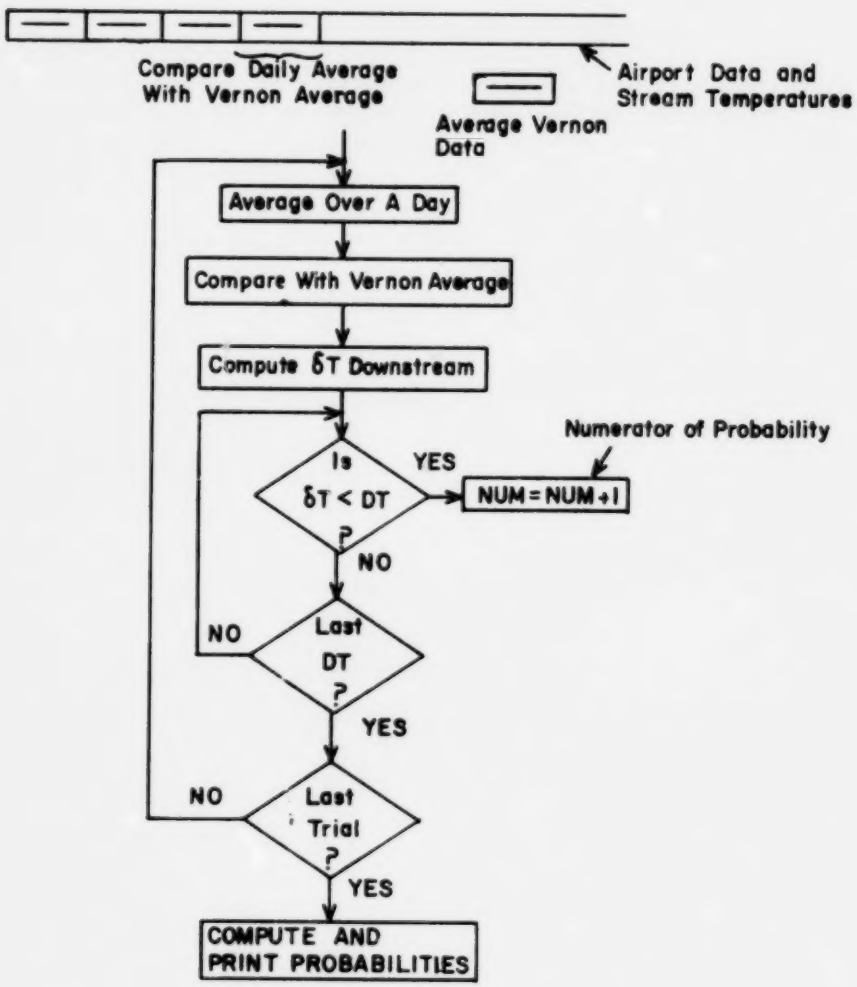

Figure 4. Model using site and station 7 temperature data

model simulates the errors of an observer remote to the site attempting to predict the site stream temperature one day ahead.

SECTION V

STUDY AREA AND METHODOLOGY

THE VERNON NUCLEAR PLANT

A program of ecological studies of the Connecticut river in the vicinity of Vernon, Vermont was initiated in 1967, prior to the operation of the Vermont Yankee Nuclear Powerplant. The preoperational studies were enlarged in scope in subsequent years and were continued after the plant became operational in October 1972. The location of the plant is shown in Figure 5, where the positions of short-term and long-term sampling stations are shown. The particulars of these sampling stations are as follows:

Station No.	Location Relative to Vernon Dam	Type
1	6.45 Miles (10.4 Km) South	Short-term
2	4.70 Miles (7.56 Km) South	Short-term
3	0.65 Miles (1.05 KM) South	Long-term
4	0.55 Miles (0.89 Km) North	Short-term
5	1.25 Miles (2.01 Km) North	Short-term
6	4.10 Miles (6.60 Km) North	Short-term
7	4.25 Miles (6.84 Km) North	Long-term
8	8.70 Miles (14.0 Km) North	Short-term

Stations 3 and 7 are permanently emplaced below and above the site respectively. Stations 3 and 7 yielded the water temperature data used in the study while meteorological data were obtained from instruments at the plant and in Keene, New Hampshire.

DATA BASE DESCRIPTION

The data base used in the project was taken from four sources:

1) Measured water temperatures at the site (See Aquatec [1974]),

2) Measured meteorological data at the site (Personal communications) ,

3) Meteorological data from Brattleboro, Vermont and Keene, New Hampshire (U.S. Weather Service),

4) Meteorological data at the Burlington, Vermont weather station (U.S. Weather Service).

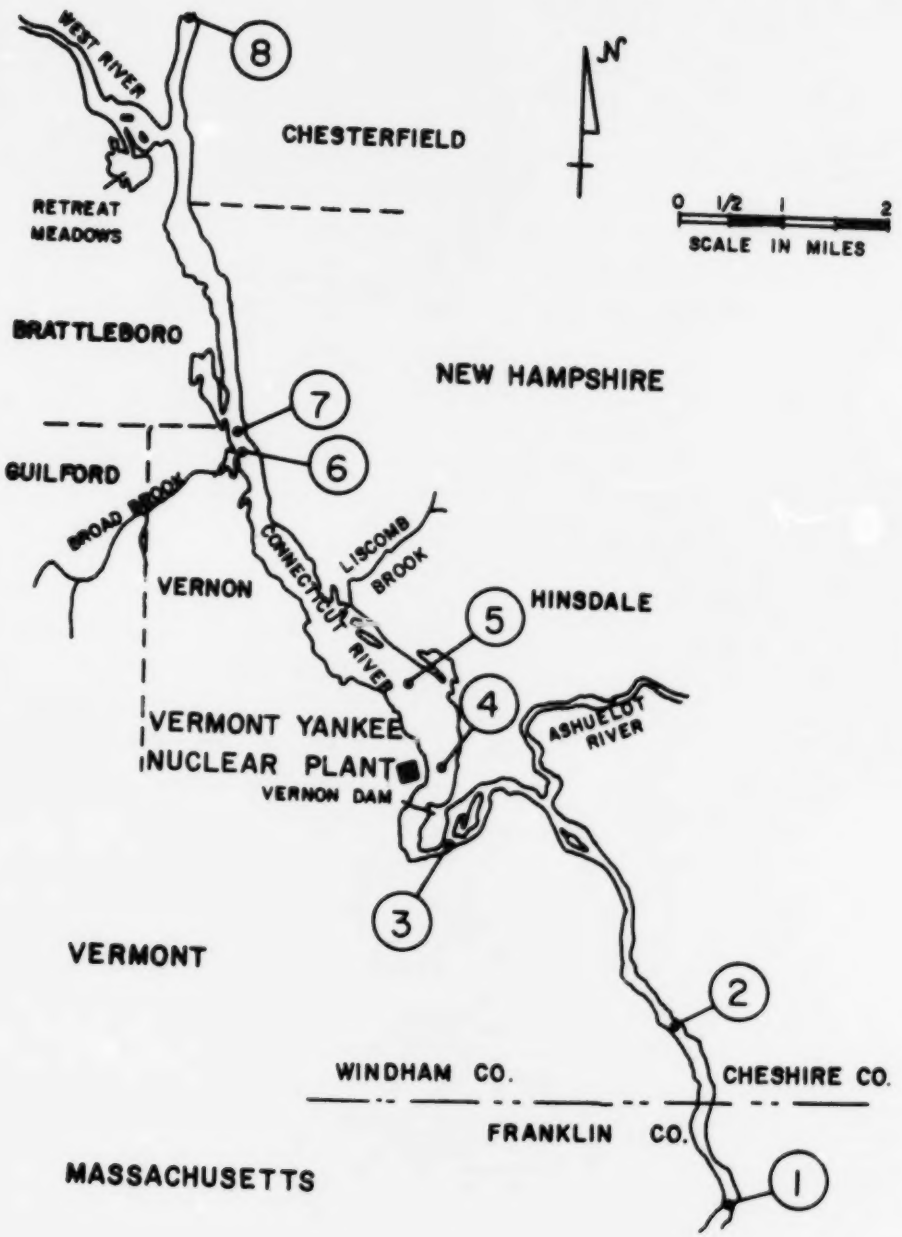

Figure 5. The Vernon nuclear plant-temperature sampling stations

The data base variables and dates for the Vernon plant example problems are as follows:

1. Burlington, Vermont Weather Station data and Vernon, Vermont water temperature data:

   Variables

   Cloud cover, air temperature, relative humidity, wind speed, water temperature from stations 3 and 7.

   Dates of Available Data

   a) May 1, 1973 to June 20, 1973

   b) August 15, 1973 to August 31, 1973 and September 12, 1973 to September 26, 1973.

   c) October 1, 1973 to October 3, 1973, October 17, 1973 to October 24, 1973, and October 27, 1973 to October 29, 1973.

   d) October 17, 1973 to October 24, 1973, October 27, 1973 to October 29, 1973, and November 1, 1973 to November 14, 1973.

2. Vernon, Vermont (and vicinity) site meteorological data:

   Daily Average Variables

   Cloud cover, air temperature, relative humidity, wind speed.

   Dates of Available Data

   June 21, 1973

   September 27, 1973

   October 30, 1973

   November 15, 1973

EXAMPLE PROBLEMS

Four example problems were constructed from the data base previously discussed. They represented spring, summer, fall, and winter conditions at the Vernon Nuclear Plant. The days studied were June 21, September 27, October 30, and November 15, 1973. The dates of the data blocks were as labeled a), b), c) and d) above in the previous section "Dates of Available Data." Computations were carried out to a point 25000 feet (7620 meters) downstream from the initial point in the model (x = 0).

SECTION VI

DISCUSSION OF RESULTS

In addition to the analyses described in Section IV, the Data Analysis Models, an order-of-magnitude error analysis was carried out using the closed-form solution developed from equation (4).

ORDER-OF-MAGNITUDE ERROR ANALYSIS

In order to gain insight into the solution of equation (4), it was logical to simplify the form of the equation and obtain a closed-form solution

$$\delta T = A\, e^{-\alpha x} + \sum_i C_i \quad , \tag{6}$$

where the C_i are the respective particular solutions associated with the errors $\delta\phi$, etc., and the constant A is related directly to the error in water temperature $\delta T(o)$ at the site, $x = 0$. The coefficient α then reveals the rate of decay of the error in temperature with distance. The June 21, 1973 averaged data were taken as an example problem:

$$\begin{aligned}
uA \text{ (Rate of flow)} &= 13{,}503 \text{ ft}^3/\text{sec} \quad , \\
El \text{ (River width)} &= 400 \text{ ft} \quad , \\
C \text{ (Cloud cover)} &= 8 \text{ tenths} \quad , \\
\bar{\alpha} \text{ (Sun angle)} &= 59^{o} \quad , \\
\phi \text{ (Relative humidity)} &= 71 \text{ percent} \quad , \\
W_2 \text{ (Wind speed)} &= 10 \text{ MPH} \quad , \\
T_{air} \text{ (Air temperature)} &= 75\ ^{o}\text{F} \quad .
\end{aligned} \tag{7}$$

These data were compared with the averaged data of May 31, 1973 to obtain the errors in the variables between these two days. This was done arbitrarily to examine the order-of-magnitude of the resulting errors in temperature. The input errors are:

δC (Error in cloud cover) = 2 tenths ,

$\delta \bar{\alpha}$ (Error in sun angle) = 5^{o} ,

$\delta \phi$ (Error in relative humidity) = 29 percent ,

δW_2 (Error in wind speed) = 5.2 MPH ,

δT_{air} (Error in air temperature) = 16 ^{o}F . (8)

Thus, the problem will yield approximate errors for predicting the water temperature on June 21, 1973 given the meteorological data from May 31, 1973. Of interest are the solutions C_i of equation (6), which are due to the respective errors in equation (8). They are found from equation (4) and Appendix D to be

1. δT_{CP} = 10.2 ^{o}F ,
2. $\delta T_{\bar{\alpha}P}$ = 1.71 ^{o}F ,
3. $\delta T_{\phi P}$ = 0.357 ^{o}F ,
4. δT_{w2P} = 1.33 ^{o}F ,
5. $\delta T_{T_{airP}}$ = 19.63 ^{o}F . (9)

Similarly, from the same source the coefficient α can be found:

$$\alpha = 0.947 \times 10^{6} \quad . \tag{10}$$

The corresponding value of x where the value of δT falls below 5 percent of the original value at $x = 0$. is

$$x = 3{,}170{,}000 \text{ feet} \quad ,$$

(966,000 meters)

$$\doteq 600 \text{ miles} \quad .$$

(966 kilometers) (11)

This order-of-magnitude study indicates important facts associated with the Vernon site:

1. Modeling the Connecticut river, which has a large flow rate in comparison with its width, produces a solution that will have errors decaying over a very long distance. This means that the error in temperature will remain virtually constant near $x = 0$.

2. The computations are far less sensitive to the environmental factors than thought previously.

3. Since the error in temperature is nearly constant near $x = 0$, the variable of primary concern is the initial error in temperature $\delta T(o)$. Thus, it appears that records of upstream temperatures in the Connecticut river would be useful for projecting average temperatures downstream.

4. Since α is inversely proportional to the volume flow Au it is possible to compute the value of α for the various flow rates, given a known flow-rate A_1U_1 and associated α , α_1 :

$$\alpha = \alpha_1 \frac{A_1U_1}{Au}$$

This expression will yield the stream flow for which a given decay rate will exist.

RESULTS OF DATA ANALYSES

The results of the four data analyses are presented in the form of probabilities for meeting given error requirements with the variables averaged over a given number of prior days. Tables I, II, and III contain results from all four problems. It should again be emphasized that these results relate to a plant operator making decisions as to the operating conditions of a given plant as opposed to a site planner predicting conditions several years in advance. As indicated on the tables, the river temperatures and the meteorological parameters are averaged over one and two days respectively.

Results in Table I indicate that an observer at the site attempting to predict the average stream temperature the following day at a position 25,000 feet (7,620 meters) downstream by averaging the previous day's meteorological data and stream temperature data would compute an

Table 1. PROBABILITIES OF MEETING GIVEN ERROR REQUIREMENTS BY AN OBSERVER AT THE VERNON SITE AVERAGING ONE DAY AND PREDICTING ONE DAY AHEAD AT A DISTANCE OF 25,000 FEET(7620 METERS) DOWNSTREAM

	Error Requirement ^{o}F (^{o}C)			
	$1^{o}F$ ($0.56^{o}C$)	$2^{o}F$ ($1.11^{o}C$)	$3^{o}F$ ($1.67^{o}C$)	$4^{o}F$ ($2.22^{o}C$)
June 21, 1973	0.6	0.9	0.94	1.0
September 27, 1973	0.613	0.935	0.963	0.968
October 30, 1973	0.769	0.923	0.923	0.923
November 15, 1973	0.75	1.0	1.0	1.0

Table 2. PROBABILITIES OF MEETING GIVEN ERROR REQUIREMENTS BY AN OBSERVER AT THE VERNON SITE AVERAGING TWO DAYS AND PREDICTING ONE DAY AHEAD AT A DISTANCE OF 25,000 FEET (7620 METERS) DOWNSTREAM

	Error Requirement ^{o}F (^{o}C)			
	$1^{o}F$ ($0.56^{o}C$)	$2^{o}F$ ($1.11^{o}C$)	$3^{o}F$ ($1.67^{o}C$)	$4^{o}F$ ($2.22^{o}C$)
June 21, 1973	0.469	0.694	0.898	0.980
September 27, 1973	0.533	0.867	0.933	0.967
October 30, 1973	0.5	0.833	0.833	0.917
November 15, 1973	0.522	0.957	1.0	1.0

Table 3. PROBABILITIES OF MEETING GIVEN ERROR REQUIREMENTS BY AN OBSERVER AT STATION 7 ONE DAY AHEAD AT THE VERNON SITE(SAME POSITION AS STATED FOR TABLE 2)

	Error Requirement ^{o}F (^{o}C)			
	$1^{o}F$ ($0.56^{o}C$)	$2^{o}F$ ($1.11^{o}C$)	$3^{o}F$ ($1.67^{o}C$)	$4^{o}F$ ($2.22^{o}C$)
June 21, 1973	0.520	0.800	0.880	0.960
October 30, 1973	0.846	0.923	0.923	0.923

approximate stream temperature within an error of 2 °F (1.11 °C) between 90 and 100 percent of the time. He would compute an approximate stream temperature within an error of 1 °F (0.56 °C) between 60 and 77 percent of the time.

Table II shows that the same observer at the site making the same prediction of an average temperature as made in Table I but using the average of two prior days' data would compute an approximate stream temperature within an error of 4 °F (2.22 °C) between 92 and 100 percent of the time. He would predict within an error of 3°F (1.67 °C) between 83 and 100 percent of the time. Similarly, a 2 °F (1.11 °C) error would be obtained between 69 and 96 percent of the time. Finally a 1 °F (0.56 °C) error would be obtained between 47 and 53 percent of the time.

Table III shows that an observer using data from station 7 above the Vernon dam, attempting to predict stream temperatures at the Vernon site by averaging a day's station 7 water temperature would compute an approximate stream temperature within an error of 4 °F (2.22 °C) between 92 and 96 percent of the time. He would predict within 3 °F (1.67 °C) between 88 and 92 percent of the time, within 2 °F (1.11 °C) between 80 and 92 percent of the time. Finally, he would predict within 1 °F (0.56 °C) between 52 and 85 percent of the time.

Thus, it is seen that predictions made at the site (with a daily average) a short period of time into the future are accurate over 90 percent of the time for a 2 °F (1.11 °C) allowable error. Averaging data over a two day period of time reduces the probability of meeting the 2 °F (1.11 °C) error to around 80 percent, which appears to be a primary influence of the travel time through this portion of the Connecticut river system, one to two days. These studies indicate that it is important to have good records of upstream temperatures from a site. With these it will be possible to predict an average temperature within 2 °F (1.11 °C). It is important to note, however, that short term fluctuations are not predictable by these methods as used in the project. Finally, the effects of season do not appear to make appreciable differences in predictions.

SECTION VII

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SECTION VIII

SYMBOLS AND VARIABLE NAMES

VARIABLE NAMES

a - General integration limit.

A - Stream cross-sectional area.

A,$\bar{A}$ - Amplitude of exponential decay function.

C - Cloud cover.

C_i - Constants.

c - Specific heat.

DT - Allowable error in stream temperature.

f - Function of several variables.

$\dot{f}$ - Derivative of f($\dot{f}$ = df/dx)/

h - Integration step.

I_1, I_2 - Integrals.

K_i - Kernel function.

ℓ, EL - Stream width.

n - Integer number.

O(-) - Of order(Order of magnitude).

P, P_i - Probability of occurence.

Q - Total heat flux.

Q_i, Q_{ij} - Particular heat fluxes.

Q_{Back} - Back radiation heat flux.

Q_{Conv}, $Q_{Convection}$ - Convective heat flux.

Q_{Evap}, $Q_{Evaporation}$ - Evaporative heat flux.

$Q_{Mis(c)}$ - Miscellaneous heat flux.

Q_{Rad}, Q_{Solar} - Radiative solar heat flux.

Q_{Ref}, $Q_{Reflective}$ - Reflective heat flux.

T - Stream temperature.

T_o - Initial stream temperature.

U,u - Average stream flow velocity.

W, W_2 - Wind speed.

x - Distance downstream.

x_i - Particular position.

$\hat{x}$ - Particular value of x.

x_{max} - Maximum value of x.

y - General function.

$\dot{y}$ - Derivative of general function.

$y(0)$, y_o - Initial value of general function.

y_i - Value of function at x_i.

z - Dummy variable of integration.

GREEK SYMBOLS

α - Decay rate coefficient.

α, $\bar{\alpha}$ - Sun angle.

δC - Error in cloud cover.

δQ - Error in total heat flux.

δT - Error in stream temperature.

$\delta T(0)$ - Initial error in stream temperature.

δT_{air} - Error in air temperature.

δT_{airp} - Particular solution for air temperature error.

δT_{cp} - Particular solution for cloud cover error.

δT_i - Particular solution.

δT_{W2p} - Particular solution for wind speed error.

$\delta T_{\bar{\alpha}p}$ - Particular solution for sun angle error.

$\delta T_{\phi p}$ - Particular solution for relative humidity error.

δW, δW_2 - Error in wind speed.

$\delta\bar{\alpha}$ - Error in sun angle.

$\delta\phi$ - Error in relative humidity.

Δx - Increment in downstream distance.

ϕ - Relative humidity in percent.

ρ - Density.

ξ - Position.

APPENDIX A

FORMAT SPECIFICATIONS

This appendix presents the procedures required for using the three codes developed during the course of the project:

1. The general stream model code, STREAM.
2. The sensitivity analysis code, SENSIT.
3. The data analysis code, MONT.

STREAM

The digital computer code STREAM performs all the necessary computations to predict the stream water temperature at any distance downstream from a given initial station. The principle of conservation of energy is applied to the stream under steady-state, steady-flow conditions. Heat transfer to and from the water in the various heat transfer modes is computed. Numerical integration is used to compute the stream temperature, with a choice of four algorithms available to the user. A listing of the STREAM code is given in APPENDIX C.

INPUT REQUIREMENTS TO STREAM

STREAM accepts the following information:

INTC: (1, 2, 3 or 4) in 6I10 FORMAT. This parameter respectively chooses Euler, Modified Euler, Runge Kutta or Adams-Moulton integration routines.

X, DX, DXPR, XEND: in 6E10.0 FORMAT. These parameters are, respectively, the initial value of the distance downstream in feet (usually 0.), the integration interval in feet, the print interval in feet, and the final value of the distance downstream in feet.

ERRØR, DXMAX: in 6E10.0 FORMAT. These parameters are used by the integration routine only and represent the error in the function in ^{o}F and the maximum integration step size in feet allowed.

TEMP, U, AREA, EL: in 6E10.0 FORMAT. These parameters are, respectively, the initial value of the temperature in ^{o}F, the average velocity of the stream in ft/sec, the cross-sectional area of the stream in ft^2, and the stream width in feet.

RHO, WMPH, TAIR, CLD, RH, ALBAR: in 6E10.0 FORMAT. These are, respectively, the density of the water (62.4 #/ft^3, here), the wind speed in MPH, the air temperature in ^{o}F, the cloud cover in tenths, the relative humidity in percent, and the average sun angle in degrees.

The final information is read in a loop of 10 sets:

PTBL(I), TTBL(I), HFGTB(I) in 6E10.0 FORMAT. These tables are, respectively, the water saturation pressure table in PSI, the water temperature table in ^{o}F, and the latent heat of evaporation table in BTU/pound, all corresponding and in order. This information is extracted from standard steam tables for the temperature range 32 to 120 ^{o}F.

The code then computes the stream temperature downstream from a given point. The output proceeds at each print position with the position X itself, the integration step DX , the stream temperature TEMP, and the derivative of the stream temperature with respect to the position variable DTEMP. Following this, other auxilliary variables are printed out: EW, EVAP, HE, HFG, HØ, EBR, and HC. These are only important for diagnostics, not the solution itself.

SENSIT

The digital computer code SENSIT performs all necessary computations to predict the error in the stream water temperature (due to the difference between the actual and approximate input data) at any distance downstream from a given initial station. The variation in the original equation is coded to examine the effects of errors of the input variables. Numerical integration is used to compute the error in stream temperature, with a choice of four algorithms available to the user. A listing of the SENSIT code is given in APPENDIX C.

INPUT REQUIREMENTS TO SENSIT

SENSIT accepts the following information:

INTC: In 6I10 FORMAT. This variable is the integration routine to be used (See STREAM for description).

X, DX, DXPR, XEND: In 6E10.0 FORMAT (See STREAM for description).

ERROR, DXMAX: In 6E10.0 FORMAT (See STREAM for description).

DT, U, AREA, EL: In 6E10.0 FORMAT. The initial temperature error DT is read in at this point (other variables are described in STREAM).

RHO, WMPH, TAIR, CLD, RH, ALBAR: In 6E10.0 FORMAT (See STREAM for variable description).

PTBL(I), TTBL(I), HFGTB(I): In 6E10.0 FORMAT (See STREAM for variable description).

DALP, DCLD, DRH, DTAIR, DWMPH: In 6E10.0 FORMAT. These variables are the errors in the respective values of the sun angle in degrees, the cloud cover in tenths, the relative humidity in percent, the air temperature in ^{o}F, and the wind velocity in MPH.

NTEMP: In 6I10 FORMAT. This is the number of temperatures given downstream.

STTBL(I), XTBL(I): In 6E10.0 FORMAT. These tables are, respectively, the water temperature and the position downstream in NTEMP sets.

The code then computes the error in the stream temperature downstream from a given point. The output proceeds at each print position with the position X itself, the integration step DX , the stream temperature TEMP, the error in the stream temperature DT, and the derivative of the error in stream temperature DDT .

Following this some auxilliary variables are also printed out: EW, DEW, EVAP, HE, HFG, HØB, HC, HLYMN, and HD, which are important for diagnostics, not for the solution itself.

MONT

The digital computer code MONT performs all the necessary calculations to obtain the probabilities for meeting a given temperature requirement. The code takes prepared data and makes a series of trials, forming data differences, and uses the sensitivity analysis code, SENSIT, to obtain the stream temperature difference at a prescribed distance downstream (in this case 25,000 feet [7620 meters]). The code makes three studies:

1. Computes the probability of meeting given error requirements given in both initial water temperature and meteorological data at the site.

2. Computes the probabilities of meeting given error requirements given errors from water temperature and meteorological time averaged data at the site.

3. Computes the probabilities of meeting given error requirements given errors from water temperature and meteorological data at a remote site, in the case of this study, at station 7 above the nuclear plant. A list of the MONT code is given in APPENDIX C.

INPUT REQUIREMENTS TO MONT

MONT accepts the following information:

NLN, LOG1: In 6I10 FORMAT. The first variable is the number of lines of data (taken every 3 hours, 8 data points per day, each day always complete); the second variable is 0 if no time averaged data appears, not zero if time averaged data appears.

Following these integer variables the major part of the data is read for the remote airport and the site water temperature in a loop of NLN lines as follows:

C(I), TA(I), PHI(I), W(I), TW(I): In 6F10.3 FORMAT. The variables are: 1) the cloud cover in tenths, 2) the air temperature in ^{o}F, 3) the relative humidity in percent, 4) the wind speed in knots, and 5) the site water temperature in ^{o}F.

Next, the average data for the actual site and the particular day are input:

UA, EL, CC, TAIR: In 6F10.3 FORMAT. These variables are 1) the flow volumes of the river in ft^3/sec, 2) the river width in ft, the cloud cover in tenths, and the air temperature in ^{o}F.

TWA, RH, WSP: In 6F10.3 FORMAT. These variables are 1) the water temperature in ^{o}F, 2) the relative humidity in percent and 3) the wind speed in knots.

If LOG1 = 0 the next two sets of data are not necessary. If LOG1 ≠ 0 the next two sets of data for the dates of past years prior to the date in question (the time-averaged data).

NTA: In 6I10 FORMAT. This value is the number of lines of time averaged data.

Following this NTA lines of data are read in as follows:

CTA(I), TATA(I), PHITA(I), WTA(I), TWTA(I): In 6F10.3 FORMAT. The variables are 1) the cloud cover in tenths, 2) the air temperature in ^{O}F, 3) the relative humidity in percent, 4) the wind speed in knots, and 5) the water temperature in ^{O}F.

Following this, the data describing the analysis are read in:

NCAS: In 6I10 FORMAT. This is the number of cases of temperature to be used in the trials.

DELT(I), I=1, NCAS: In 6E10.3 FORMAT. These are input in sequence, the first six values of allowed temperature on the first line, the second six on the second line, etc.

NDAS: In 6I10 FORMAT. This is the number of day cases to be tried.

IDAS(I), I=1, NDAS: In 6I10 FORMAT. These are the number of days of data to be averaged in each day case. They are input in sequence, six values per line.

Following this, 10 lines of data are input for the sensitivity analysis program, which is a subroutine in this case.

PTBL(I), TTBL(I), HFGTB(I): In 6E10.3 FORMAT (See STREAM for variables description).

The next data to be input are 1) the number of days since March 21 (the vernal equinox) which is required to estimate the coefficient involved with the sun heating effect, and 2) the latitude of the plant in degrees:

DM21, BETA: In 6E10.0 FORMAT.

The last data to be input are the daily average of the water temperature at the remote site:

T7(I), I=1, Number of Days in 6E10.3 FORMAT.

The code then computes the errors in the stream temperature downstream from a given point considering the days to be averaged as requested. Three sets of input errors are examined:

1. The airport meteorological data and stream temperature against itself (simulating values at a site).

2. The time-averaged meteorological and stream temperature data against the site data.

3. The airport meteorological data and the remote site water temperature data against the site data water temperatures (simulating predictions from a distance).

These are compared to the requirements on temperature for each case. The number of cases for which the requirements are satisfied are recorded and printed out in the form of probability values.

APPENDIX B

INPUT DATA

This Appendix contains the input for the four example problems.

EXAMPLE PROBLEM INPUT

The input for the four example problems has the following format:

1. The number of lines of data, 8 lines per day (3 hour intevals).

2. The time averaged data logic parameter (1 means time averaged data appears, 0 means no time averaged data appears).

3. The data now appears by line as follows:

   a) Cloud cover in tenths.

   b) Air temperature in ^{o}F.

   c) Relative humidity in percent.

   d) Wind speed in knots.

   e) Water temperature ^{o}F.

4. The average data (over a day) for the plant site then is:

   a) The flow volume, UA, ft^3/sec.

   b) The river width, EL, ft.

   c) The cloud cover at the site in tenths.

   d) The air temperature ^{o}F

   e) The water temperature ^{o}F.

   f) The relative humidity in percent.

   g) The wind speed in knots.

5. If time-averaged data appears the following then is required:

   a) The number of time-averaged data lines.

   b) The lines of data as follows

      1) Cloud cover in tenths.

      2) Air temperature ^{o}F.

      3) Relative humidity in percent.

      4) Wind speed in knots.

      5) The water temperature in ^{o}F.

6. The control data for the data analysis is next.

   a) The number of cases of error in temperature.

   b) The allowed errors in temperature.

   c) The number of cases for days of data to be averaged.

   d) The actual number of days of data to be averaged.

7. The tables of vapor pressure and latent heat (no changes except for very unusual conditions).

8. The days to the date in question past March 21.

9. The latitude of the site in degrees.

10. The daily averages of the water temperatures at the remote site. In this case station 7.

PRINTOUT FOR THE FOUR EXAMPLE PROBLEMS

JUNE 21, 1973

MAY 1 to JUNE 20, 1973

RUN

NUMBER OF DATA LINES= 40 RTIME AV. LOGIC= 0

CLD COVER	AIRTEMP	REL HUM	WIND SPD	WATER TEMP
.000	35.000	92.000	4.000	48.000
8.000	33.000	96.000	3.000	48.000
8.000	39.000	93.000	4.000	48.200
9.000	56.000	60.000	5.000	48.500
10.000	56.000	57.000	4.000	48.500
10.000	61.000	52.000	4.000	48.700
10.000	53.000	80.000	4.000	49.000
10.000	54.000	96.000	5.000	49.000
10.000	56.000	90.000	7.000	49.200
10.000	55.000	90.000	8.000	49.200
10.000	56.000	87.000	12.000	49.500
5.000	66.000	68.000	14.000	50.000
10.000	72.000	57.000	14.000	50.500
10.000	73.000	55.000	9.000	51.000
10.000	68.000	68.000	9.000	51.000
10.000	61.000	90.000	4.000	51.000
10.000	64.000	84.000	4.000	51.200
10.000	65.000	78.000	10.000	51.500
8.000	63.000	90.000	11.000	51.700
10.000	70.000	73.000	8.000	52.200
10.000	75.000	54.000	10.000	52.700
10.000	55.000	100.000	7.000	53.000
10.000	50.000	93.000	10.000	52.500
10.000	50.000	80.000	4.000	52.200
10.000	48.000	68.000	5.000	52.000

9.000	46.000	71.000	2.000	52.000
10.000	45.000	80.000	5.000	52.000
10.000	49.000	66.000	6.000	52.200
10.000	50.000	59.000	8.000	52.500
10.000	51.000	52.000	6.000	52.700
10.000	48.000	63.000	4.000	52.500
10.000	46.000	58.000	3.000	52.500
10.000	43.000	76.000	3.000	52.200
10.000	42.000	76.000	2.000	52.000
10.000	42.000	89.000	3.000	52.000
10.000	45.000	77.000	6.000	52.000
10.000	47.000	66.000	7.000	52.000
10.000	45.000	80.000	4.000	52.200
10.000	43.000	89.000	3.000	52.200
10.000	43.000	93.000	3.000	52.000
10.000	43.000	96.000	4.000	51.700
10.000	43.000	93.000	5.000	51.500
10.000	45.000	93.000	9.000	51.500
8.000	53.000	62.000	10.000	51.700
9.000	55.000	51.000	12.000	52.000
9.000	56.000	51.000	11.000	52.500
2.000	53.000	57.000	6.000	52.200
.000	45.000	65.000	4.000	52.000
.000	37.000	89.000	.000	51.500
.000	32.000	96.000	.000	51.200
.000	39.000	93.000	.000	51.000
.000	54.000	53.000	11.000	51.000
.000	58.000	44.000	14.000	51.700
6.000	62.000	34.000	10.000	53.000

2.000	55.000	47.000	4.000	53.200
.000	43.000	83.000	2.000	52.700
1.000	38.000	89.000	.000	52.500
4.000	35.000	92.000	3.000	52.000
5.000	53.000	69.000	14.000	52.000
10.000	63.000	48.000	14.000	52.200
10.000	68.000	41.000	15.000	52.700
10.000	63.000	40.000	16.000	53.500
10.000	57.000	57.000	6.000	53.700
10.000	54.000	69.000	12.000	53.500
10.000	49.000	93.000	9.000	53.500
10.000	50.000	96.000	3.000	53.000
10.000	50.000	96.000	4.000	53.000
10.000	55.000	93.000	7.000	52.700
10.000	56.000	93.000	8.000	52.700
10.000	57.000	83.000	9.000	53.000
10.000	55.000	86.000	5.000	53.200
10.000	53.000	93.000	6.000	53.200
10.000	54.000	90.000	5.000	53.200
10.000	55.000	96.000	7.000	53.000
7.000	58.000	87.000	8.000	52.500
10.000	64.000	75.000	13.000	52.500
10.000	71.000	64.000	12.000	53.000
10.000	75.000	50.000	12.000	54.000
10.000	68.000	63.000	5.000	54.000
10.000	62.000	67.000	18.000	54.000
10.000	57.000	100.000	8.000	54.000
10.000	57.000	93.000	12.000	54.200

10.000	56.000	93.000	11.000	54.500
10.000	57.000	93.000	10.000	54.500
7.000	52.000	63.000	8.000	54.700
8.000	56.000	83.000	5.000	55.000
9.000	56.000	80.000	4.000	55.000
7.000	54.000	72.000	9.000	55.000
10.000	52.000	69.000	9.000	55.200
9.000	46.000	80.000	3.000	55.000
9.000	43.000	80.000	11.000	55.000
10.000	57.000	69.000	13.000	55.500
10.000	55.000	77.000	9.000	56.200
10.000	51.000	100.000	4.000	56.700
7.000	53.000	83.000	5.000	56.500
9.000	49.000	86.000	4.000	56.200
10.000	48.000	89.000	3.000	56.000
10.000	45.000	86.000	5.000	55.700
10.000	46.000	90.000	10.000	55.500
10.000	50.000	80.000	13.000	56.000
10.000	52.000	88.000	14.000	56.200
10.000	51.000	84.000	10.000	56.700
10.000	51.000	97.000	9.000	56.500
8.000	48.000	86.000	5.000	56.000
7.000	45.000	77.000	4.000	56.000
9.000	42.000	83.000	5.000	55.500
10.000	45.000	77.000	3.000	55.200
10.000	50.000	69.000	10.000	55.200
10.000	53.000	83.000	7.000	55.700
10.000	51.000	84.000	8.000	56.000
8.000	49.000	71.000	9.000	56.000

.000	40.000	93.000	2.000	55.500
.000	37.000	96.000	.000	55.000
3.000	33.000	100.000	3.000	54.500
5.000	40.000	96.000	3.000	54.500
9.000	56.000	60.000	3.000	54.500
10.000	55.000	64.000	10.000	54.700
10.000	52.000	83.000	9.000	55.000
10.000	49.000	96.000	5.000	55.000
10.000	48.000	100.000	4.000	55.000
10.000	46.000	100.000	4.000	54.700
10.000	45.000	93.000	9.000	54.700
7.000	47.000	71.000	7.000	54.200
2.000	54.000	49.000	5.000	54.500
4.000	60.000	39.000	13.000	55.000
1.000	62.000	38.000	10.000	55.200
1.000	59.000	42.000	8.000	55.000
1.000	55.000	47.000	7.000	55.000
8.000	54.000	49.000	11.000	55.000
8.000	54.000	55.000	10.000	54.700
5.000	55.000	57.000	10.000	54.500
7.000	64.000	47.000	13.000	54.500
6.000	68.000	39.000	10.000	54.700
10.000	52.000	74.000	14.000	55.000
10.000	45.000	86.000	9.000	54.700
10.000	43.000	93.000	9.000	54.700
10.000	42.000	96.000	5.000	54.700
10.000	42.000	100.000	4.000	54.700
10.000	48.000	83.000	10.000	54.700

10.000	48.000	86.000	4.000	54.700
10.000	49.000	89.000	4.000	54.700
10.000	51.000	77.000	5.000	54.500
10.000	49.000	83.000	5.000	54.000
10.000	42.000	96.000	7.000	53.700
10.000	42.000	100.000	10.000	53.000
10.000	41.000	100.000	10.000	52.500
10.000	42.000	96.000	10.000	52.500
10.000	45.000	93.000	13.000	52.500
10.000	46.000	93.000	10.000	52.500
10.000	46.000	93.000	8.000	52.500
10.000	46.000	93.000	9.000	52.500
10.000	47.000	86.000	7.000	52.500
10.000	49.000	77.000	7.000	51.700
10.000	48.000	80.000	5.000	51.500
6.000	50.000	80.000	3.000	51.200
5.000	60.000	62.000	3.000	51.000
9.000	67.000	49.000	4.000	51.000
10.000	63.000	50.000	10.000	51.000
10.000	60.000	65.000	3.000	51.000
10.000	53.000	90.000	3.000	51.000
10.000	51.000	100.000	5.000	51.000
10.000	51.000	100.000	6.000	51.000
10.000	50.000	100.000	11.000	50.700
10.000	52.000	100.000	13.000	50.500
10.000	51.000	96.000	14.000	50.200
10.000	49.000	96.000	15.000	50.200
10.000	48.000	96.000	14.000	50.200
10.000	47.000	100.000	13.000	50.200

10.000	47.000	100.000	8.000	50.200
10.000	47.000	100.000	7.000	50.200
10.000	47.000	100.000	9.000	50.000
10.000	50.000	86.000	7.000	50.000
10.000	54.000	75.000	8.000	50.200
7.000	58.000	65.000	10.000	50.500
6.000	56.000	62.000	4.000	51.000
.000	43.000	96.000	2.000	51.000
.000	39.000	100.000	3.000	50.500
.000	37.000	100.000	2.000	50.000
.000	45.000	100.000	3.000	50.000
2.000	60.000	70.000	3.000	50.000
8.000	67.000	40.000	6.000	50.500
8.000	68.000	36.000	7.000	51.200
9.000	63.000	43.000	7.000	51.500
9.000	52.000	74.000	4.000	51.700
.000	47.000	89.000	7.000	51.500
.000	42.000	96.000	2.000	51.500
3.000	51.000	90.000	6.000	51.500
4.000	60.000	70.000	8.000	51.700
4.000	67.000	55.000	12.000	52.000
3.000	68.000	51.000	13.000	52.700
3.000	63.000	50.000	6.000	53.500
3.000	52.000	83.000	3.000	53.500
2.000	45.000	96.000	2.000	53.500
10.000	46.000	100.000	5.000	53.700
10.000	47.000	100.000	5.000	53.700
3.000	54.000	86.000	8.000	53.700

1.000	64.000	65.000	8.000	54.000
2.000	66.000	51.000	3.000	54.000
4.000	63.000	65.000	6.000	54.000
6.000	55.000	80.000	7.000	54.000
2.000	50.000	83.000	3.000	54.000
8.000	50.000	86.000	6.000	54.000
7.000	55.000	75.000	7.000	53.700
9.000	58.000	67.000	7.000	53.700
7.000	62.000	58.000	5.000	53.500
2.000	64.000	54.000	4.000	53.500
8.000	61.000	58.000	4.000	53.500
8.000	55.000	80.000	7.000	53.500
6.000	54.000	75.000	10.000	53.500
10.000	51.000	80.000	7.000	53.500
1.000	55.000	75.000	8.000	53.500
5.000	60.000	62.000	15.000	53.700
3.000	65.000	54.000	10.000	54.000
1.000	68.000	49.000	13.000	54.500
9.000	63.000	60.000	6.000	54.700
9.000	57.000	72.000	7.000	54.700
10.000	54.000	80.000	7.000	54.700
10.000	52.000	90.000	10.000	54.700
10.000	51.000	96.000	10.000	55.000
10.000	54.000	100.000	11.000	55.200
10.000	57.000	93.000	9.000	55.500
10.000	59.000	90.000	10.000	55.700
10.000	60.000	93.000	13.000	55.500
10.000	61.000	97.000	10.000	55.200
10.000	63.000	97.000	10.000	55.200

10.000	62.000	97.000	4.000	55.500
10.000	61.000	100.000	8.000	55.500
10.000	62.000	100.000	6.000	55.500
8.000	69.000	73.000	9.000	56.500
7.000	72.000	57.000	8.000	57.200
10.000	60.000	87.000	5.000	57.700
10.000	58.000	93.000	6.000	57.700
10.000	57.000	93.000	.000	57.700
10.000	55.000	100.000	.000	57.700
10.000	56.000	96.000	3.000	57.500
10.000	62.000	75.000	2.000	57.700
9.000	68.000	55.000	5.000	58.000
10.000	64.000	54.000	5.000	58.200
3.000	63.000	65.000	.000	58.200
10.000	58.000	90.000	3.000	58.500
10.000	56.000	96.000	3.000	58.500
10.000	56.000	100.000	4.000	58.500
10.000	56.000	100.000	.000	59.000
10.000	59.000	100.000	4.000	59.000
10.000	60.000	84.000	10.000	59.500
10.000	64.000	73.000	4.000	60.000
10.000	62.000	73.000	4.000	60.000
3.000	58.000	81.000	6.000	60.000
1.000	56.000	80.000	10.000	60.200
.000	54.000	80.000	8.000	60.200
9.000	60.000	70.000	13.000	60.700
9.000	64.000	68.000	14.000	61.500
10.000	62.000	75.000	9.000	62.000

9.000	66.000	65.000	5.000	61.700
10.000	56.000	90.000	8.000	61.500
10.000	53.000	96.000	6.000	61.000
2.000	47.000	83.000	5.000	61.000
6.000	41.000	96.000	4.000	61.000
3.000	47.000	68.000	12.000	60.700
2.000	51.000	46.000	10.000	60.700
1.000	57.000	44.000	12.000	61.500
.00	59.000	44.000	10.000	61.700
.000	56.000	45.000	5.000	61.500
.000	43.000	83.000	3.000	61.200
.000	39.000	93.000	3.000	61.000
.000	36.000	96.000	.000	60.700
.000	47.000	83.000	3.000	60.700
.000	62.000	41.000	10.000	61.000
.000	68.000	33.000	5.000	61.200
4.000	70.000	36.000	8.000	61.500
8.000	65.000	52.000	2.000	61.500
6.000	53.000	86.000	3.000	61.200
6.000	49.000	89.000	3.000	61.000
10.000	53.000	86.000	4.000	61.000
10.000	58.000	84.000	9.000	61.000
10.000	57.000	96.000	6.000	61.200
10.000	60.000	100.000	.000	61.500
10.000	64.000	97.000	5.000	62.000
10.000	63.000	100.000	4.000	62.000
10.000	62.000	100.000	3.000	61.500
10.000	60.000	100.000	3.000	61.200
10.000	60.000	100.000	3.000	61.200

8.000	65.000	100.000	3.000	61.000
6.000	77.000	74.000	12.000	61.000
10.000	80.000	65.000	12.000	61.500
10.000	76.000	76.000	4.000	61.700
9.000	76.000	76.000	7.000	61.700
8.000	68.000	87.000	5.000	62.000
8.000	67.000	87.000	8.000	62.000
10.000	71.000	81.000	10.000	62.200
10.000	74.000	76.000	7.000	62.200
7.000	78.000	71.000	13.000	62.700
7.000	85.000	61.000	12.000	63.000
10.000	71.000	90.000	7.000	63.100
7.000	72.000	84.000	5.000	63.500
7.000	72.000	76.000	10.000	63.000
10.000	72.000	82.000	13.000	62.700
8.000	70.000	84.000	16.000	62.700
10.000	70.000	84.000	14.000	62.500
8.000	76.000	66.000	13.000	62.700
7.000	79.000	52.000	8.000	63.000
4.000	80.000	41.000	13.000	64.000
.000	75.000	45.000	8.000	64.500
.000	61.000	75.000	5.000	64.700
.000	56.000	93.000	3.000	64.500
1.000	55.000	93.000	3.000	64.200
8.000	68.000	68.000	10.000	64.000
5.000	77.000	56.000	11.000	64.000
8.000	81.000	51.000	12.000	64.700
7.000	84.000	46.000	10.000	65.200

8.000	79.000	52.000	7.000	65.500
2.000	71.000	64.000	8.000	65.700
3.000	73.000	57.000	12.000	65.700
5.000	71.000	61.000	13.000	65.700
10.000	71.000	66.000	10.000	65.500
10.000	72.000	68.000	11.000	65.500
9.000	79.000	62.000	12.000	66.200
3.000	82.000	43.000	10.000	67.000
7.000	77.000	50.000	8.000	67.500
2.000	72.000	50.000	8.000	67.500
2.000	67.000	53.000	7.000	67.000
2.000	61.000	67.000	5.000	67.000
5.000	64.000	68.000	8.000	66.500
1.000	71.000	49.000	6.000	66.700
8.000	76.000	43.000	8.000	67.500
6.000	79.000	41.000	6.000	68.500
10.000	70.000	71.000	4.000	69.000
7.000	63.000	93.000	3.000	69.000
10.000	64.000	90.000	5.000	68.500
10.000	66.000	78.000	3.000	68.000
10.000	72.000	66.000	8.000	67.500
8.000	73.000	62.000	10.000	67.700
2.000	86.000	55.000	5.000	68.500
6.000	86.000	50.000	8.000	69.700
10.000	78.000	62.000	5.000	60.200
10.000	67.000	90.000	4.000	70.200
2.000	66.000	93.000	3.000	69.700
8.000	66.000	93.000	5.000	69.700
4.000	73.000	82.000	8.000	69.500

5.000	78.000	79.000	11.000	70.200
2.000	85.000	61.000	11.000	71.000
10.000	70.000	93.000	6.000	72.500
10.000	68.000	100.000	6.000	72.200
8.000	66.000	100.000	.000	72.000
5.000	64.000	100.000	3.000	71.700
10.000	64.000	100.000	4.000	71.700
10.000	68.000	93.000	3.000	72.000
10.000	71.000	90.000	5.000	72.000
10.000	66.000	100.000	6.000	72.000
6.000	70.000	76.000	5.000	71.500
4.000	71.000	68.000	5.000	72.000
.000	61.000	90.000	3.000	72.200
8.000	61.000	84.000	5.000	72.000
8.000	57.000	96.000	3.000	72.000
2.000	62.000	87.000	3.000	71.700
3.000	70.000	53.000	7.000	71.700
8.000	73.000	41.000	11.000	71.700
3.000	75.000	34.000	14.000	71.500
5.000	70.000	38.000	13.000	71.500
.000	61.000	33.000	13.000	70.500
.000	53.000	64.000	8.000	70.000
2.000	50.000	71.000	8.000	69.500
9.000	55.000	51.000	12.000	68.700
10.000	55.000	55.000	8.000	68.500
10.000	57.000	60.000	6.000	68.700
10.000	58.000	55.000	7.000	68.500
10.000	55.000	59.000	6.000	68.500

10.000	51.000	80.000	2.000	68.500
10.000	49.000	89.000	4.000	68.000
10.000	48.000	96.000	4.000	67.500
10.000	50.000	96.000	7.000	67.000
10.000	52.000	96.000	7.000	67.000
10.000	52.000	100.000	5.000	67.500
10.000	53.000	100.000	6.000	68.500
10.000	52.000	100.000	11.000	68.500
10.000	52.000	100.000	12.000	68.500
10.000	49.000	100.000	4.000	67.700
5.000	45.000	96.000	5.000	67.500
3.000	51.000	90.000	8.000	67.000
6.000	57.000	72.000	8.000	67.000
4.000	62.000	58.000	11.000	67.200
3.000	65.000	50.000	10.000	67.700
3.000	62.000	54.000	8.000	67.500
5.000	49.000	93.000	3.000	66.500
7.000	45.000	100.000	2.000	65.700
8.000	43.000	100.000	3.000	65.000
10.000	50.000	93.000	4.000	63.500
10.000	61.000	75.000	10.000	62.200
10.000	62.000	73.000	11.000	62.200
8.000	65.000	61.000	12.000	62.700
10.000	59.000	75.000	10.000	62.700
2.000	55.000	90.000	5.000	62.200
.000	55.000	93.000	5.000	61.200
10.000	55.000	96.000	2.000	60.200
10.000	57.000	93.000	3.000	59.500
10.000	65.000	78.000	5.000	59.000

10.000	71.000	66.000	3.000	59.000
10.000	74.000	60.000	6.000	59.000
4.000	72.000	64.000	3.000	59.000
3.000	63.000	84.000	5.000	59.000
7.000	59.000	93.000	3.000	58.700
10.000	64.000	90.000	4.000	58.500
10.000	68.000	87.000	10.000	58.200
2.000	76.000	66.000	12.000	58.500
8.000	83.000	46.000	16.000	59.500
8.000	83.000	51.000	11.000	60.000
3.000	78.000	62.000	8.000	60.200
3.000	73.000	76.000	7.000	60.200

UA= 13503.000K WIDTH= 400.000CLD COVER= 8.000TEMP AIR= 75.000

TEMP WATER= 62.000REL HUM= 71.000WIND SPEED= 8.700

NUMBER OF CASES= 4

ALLOWED DTS

  .100000E 01

  .200000E 01

  .300000E 01

  .400000E 01

NUMBER OF DAYS AVERAGED= 2

DAYS AVERAGED

  1

  2

PTBL1 TTBL1 HFGTB1

****

.685E-01 .32CE 02 .108E 04
.122E 00 .40CE 02 .107E 04
.178E 00 .50CE 02 .107E 04
.256E 00 .60CE 02 .106E 04
.363E 00 .70CE 02 .105E 04

.507E 00 .80CE 02 .105E 04
.698E 00 .90CE 02 .104E 04
.949E 00 .10CE 03 .104E 04
.127E 01 .11CE 03 .103E 04
.169E 01 .12CE 03 .103E 04

DAYS SINCE MARCH 21= 41.000BETA= 45.000

ADDITIONAL DATA FOR STATION 7 ABOVE THE DAM

TEMPERATURES AT STATION 7, ^{O}F, DAILY AVERAGES, MAY 1-JUNE 21

48.9, 50.7, 52.3, 52.4, 52.0, 51.8, 51.9, 52.9,
53.0, 53.1, 54.5, 55.2, 55.0, 54.5, 54.2, 54.2,
53.6, 52.4, 51.4, 50.8, 51.0, 50.6, 52.3, 53.9,
53.7, 54.1, 53.8, 54.3, 55.3, 56.3, 57.9, 59.0,
59.4, 58.8, 58.9, 60.0, 60.9, 62.3, 63.3, 64.6,
65.2, 66.8, 69.2, 69.3, 69.0, 67.3, 66.9, 66.1,
62.4, 59.3, 59.9

SEPTEMBER 27, 1973
AUGUST 15 to 31 and SEPTEMBER 12 to 26

NUMBER OF DATA LINES= 256TIME AV. LOGIC= 0

CLD COVER	AIRTEMP	REL HUM	WIND SPD	WATER TEMP
5.000	66.000	87.000	6.000	78.000
5.000	64.000	90.000	6.000	77.500
10.000	66.000	90.000	7.000	77.200
10.000	70.000	84.000	8.000	77.500
9.000	75.000	69.000	10.000	77.200
10.000	75.000	66.000	10.000	77.000
10.000	71.000	76.000	6.000	77.000
4.000	66.000	87.000	5.000	77.000
.000	62.000	93.000	3.000	76.700
9.000	62.000	97.000	3.000	76.700
10.000	62.000	100.000	4.000	76.000
10.000	67.000	93.000	4.000	75.700
1.000	77.000	62.000	5.000	75.700
1.000	79.000	47.000	9.000	76.500
.000	75.000	58.000	3.000	77.000
.000	65.000	87.000	3.000	76.500
.000	62.000	93.000	3.000	76.200
1.000	59.000	97.000	4.000	76.500
8.000	62.000	97.000	4.000	76.500
8.000	75.000	71.000	5.000	76.500
8.000	82.000	55.000	5.000	76.500
7.000	83.000	51.000	7.000	77.500
9.000	79.000	65.000	4.000	77.700
9.000	68.000	93.000	3.000	77.200
5.000	66.000	93.000	3.000	76.700
5.000	64.000	97.000	3.000	76.700

3.000	66.000	97.000	3.000	76.700
8.000	76.000	71.000	6.000	76.700
8.000	85.000	57.000	4.000	77.200
9.000	85.000	51.000	9.000	77.000
10.000	67.000	87.000	11.000	77.000
8.000	66.000	93.000	5.000	76.700
3.000	65.000	93.000	5.000	76.500
8.000	63.000	97.000	6.000	76.500
5.000	63.000	100.000	4.000	75.700
7.000	74.000	84.000	4.000	76.000
5.000	80.000	67.000	4.000	76.700
9.000	69.000	84.000	9.000	77.200
9.000	72.000	84.000	5.000	77.200
4.000	67.000	93.000	5.000	76.500
3.000	63.000	97.000	3.000	76.200
3.000	60.000	97.000	5.000	75.700
.000	63.000	97.000	4.000	75.700
.000	74.000	71.000	10.000	76.000
4.000	79.000	60.000	5.000	76.200
2.000	81.000	54.000	5.000	76.700
1.000	73.000	69.000	6.000	77.200
.000	67.000	84.000	3.000	76.500
.000	63.000	90.000	6.000	76.200
.000	61.000	93.000	7.000	76.200
.000	62.000	97.000	3.000	75.200
4.000	75.000	69.000	11.000	75.500
8.000	80.000	49.000	10.000	76.000
8.000	80.000	56.000	10.000	76.500

10.000	70.000	79.000	6.000	76.700
10.000	68.000	84.000	5.000	76.500
10.000	69.000	76.000	8.000	75.500
10.000	67.000	73.000	13.000	75.200
10.000	66.000	81.000	13.000	75.000
10.000	65.000	84.000	11.000	75.000
10.000	61.000	93.000	10.000	75.200
10.000	61.000	90.000	8.000	76.000
8.000	61.000	75.000	4.000	76.000
1.000	54.000	90.000	4.000	76.000
2.000	51.000	93.000	3.000	75.500
.000	47.000	100.000	3.000	74.500
.000	50.000	100.000	5.000	73.500
.000	64.000	65.000	6.000	73.500
9.000	68.000	55.000	9.000	74.000
7.000	70.000	49.000	5.000	75.000
9.000	67.000	66.000	4.000	75.000
10.000	67.000	61.000	3.000	74.500
10.000	65.000	73.000	8.000	73.700
10.000	64.000	75.000	5.000	73.500
1.000	60.000	81.000	7.000	73.200
.000	64.000	58.000	8.000	73.200
.000	68.000	49.000	6.000	73.500
.000	71.000	48.000	8.000	74.500
1.000	65.000	61.000	4.000	75.000
.000	55.000	90.000	5.000	74.500
.000	52.000	93.000	3.000	73.700
.000	49.000	96.000	4.000	73.500
.000	51.000	100.000	5.000	73.200

1.000	69.000	68.000	6.000	73.200
6.000	76.000	48.000	9.000	74.000
9.000	77.000	48.000	8.000	74.000
8.000	69.000	73.000	5.000	73.500
7.000	63.000	90.000	4.000	73.000
10.000	61.000	97.000	4.000	72.700
10.000	62.000	93.000	4.000	72.700
10.000	64.000	90.000	5.000	72.700
10.000	65.000	93.000	5.000	73.000
10.000	75.000	69.000	6.000	74.000
10.000	76.000	66.000	6.000	74.000
10.000	72.000	84.000	4.000	73.700
10.000	70.000	90.000	4.000	73.500
10.000	68.000	93.000	5.000	73.500
10.000	66.000	100.000	4.000	73.500
10.000	67.000	97.000	4.000	73.500
.000	79.000	77.000	8.000	74.000
6.000	84.000	65.000	4.000	74.500
6.000	86.000	63.000	4.000	75.000
4.000	81.000	79.000	4.000	75.000
5.000	78.000	88.000	9.000	75.500
10.000	77.000	88.000	9.000	75.500
10.000	68.000	93.000	5.000	75.200
9.000	68.000	100.000	4.000	75.000
4.000	76.000	97.000	4.000	75.500
2.000	83.000	74.000	15.000	76.000
.000	85.000	53.000	9.000	76.500
10.000	77.000	64.000	5.000	77.000

5.000	69.000	81.000	4.000	76.500
.000	64.000	93.000	3.000	76.000
.000	61.000	97.000	3.000	75.700
3.000	63.000	100.000	4.000	75.500
4.000	77.000	74.000	8.000	75.500
2.000	85.000	61.000	11.000	76.000
2.000	87.000	57.000	5.000	77.000
5.000	81.000	79.000	5.000	77.000
3.000	76.000	82.000	5.000	77.000
3.000	72.000	93.000	3.000	76.500
9.000	73.000	87.000	4.000	76.200
10.000	75.000	85.000	5.000	76.000
8.000	84.000	67.000	9.000	76.200
9.000	90.000	56.000	9.000	77.000
5.000	91.000	50.000	10.000	77.500
10.000	79.000	69.000	8.000	77.700
4.000	74.000	82.000	4.000	77.200
2.000	70.000	93.000	3.000	76.700
9.000	68.000	100.000	4.000	77.000
5.000	69.000	100.000	5.000	77.000
2.000	83.000	67.000	5.000	77.500
4.000	88.000	61.000	5.000	77.500
10.000	74.000	82.000	12.000	78.500
10.000	74.000	82.000	3.000	79.000
10.000	71.000	90.000	7.000	79.000
10.000	60.000	67.000	7.000	71.200
5.000	56.000	75.000	6.000	70.700
8.000	56.000	75.000	7.000	70.200
7.000	60.000	62.000	9.000	70.500

10.000	62.000	48.000	9.000	70.500
10.000	62.000	50.000	8.000	70.500
10.000	60.000	58.000	6.000	70.500
10.000	56.000	78.000	3.000	70.500
10.000	54.000	83.000	3.000	70.200
4.000	51.000	90.000	3.000	70.000
9.000	51.000	93.000	3.000	69.500
5.000	61.000	58.000	10.000	69.500
9.000	63.000	46.000	5.000	70.200
4.000	64.000	47.000	8.000	70.500
9.000	57.000	69.000	3.000	71.000
10.000	52.000	83.000	3.000	70.500
10.000	51.000	86.000	6.000	70.200
10.000	50.000	86.000	4.000	69.700
10.000	51.000	90.000	7.000	69.500
10.000	59.000	70.000	8.000	69.500
10.000	59.000	75.000	5.000	68.500
10.000	55.000	90.000	5.000	68.200
10.000	54.000	93.000	8.000	68.000
10.000	54.000	96.000	4.000	68.000
10.000	54.000	96.000	6.000	68.000
10.000	54.000	96.000	4.000	67.700
10.000	54.000	96.000	6.000	67.500
10.000	55.000	100.000	3.000	67.700
10.000	57.000	96.000	8.000	67.700
8.000	59.000	93.000	5.000	67.700
9.000	57.000	93.000	5.000	67.700
10.000	57.000	96.000	7.000	67.700

10.000	58.000	93.000	11.000	67.500
10.000	58.000	90.000	11.000	67.200
10.000	56.000	83.000	12.000	67.000
9.000	54.000	75.000	13.000	67.000
9.000	54.000	69.000	12.000	67.000
9.000	53.000	72.000	12.000	67.000
6.000	51.000	69.000	9.000	66.700
9.000	51.000	71.000	11.000	66.700
10.000	50.000	71.000	10.000	66.500
.000	42.000	86.000	3.000	66.000
.000	41.000	96.000	4.000	65.500
4.000	52.000	55.000	8.000	66.000
8.000	55.000	53.000	11.000	66.700
6.000	56.000	51.000	5.000	66.700
10.000	50.000	74.000	4.000	66.200
10.000	48.000	93.000	7.000	66.000
10.000	50.000	93.000	10.000	65.700
10.000	50.000	96.000	8.000	65.700
10.000	52.000	96.000	12.000	65.000
10.000	52.000	96.000	4.000	65.000
10.000	54.000	96.000	6.000	65.500
10.000	51.000	96.000	13.000	65.200
10.000	51.000	93.000	13.000	64.700
2.000	47.000	93.000	4.000	64.200
8.000	41.000	96.000	3.000	64.000
4.000	39.000	100.000	3.000	63.500
9.000	40.000	100.000	3.000	63.700
2.000	54.000	90.000	8.000	64.500
.000	61.000	72.000	10.000	64.700

2.000	63.000	60.000	13.000	64.200
1.000	55.000	69.000	7.000	63.700
6.000	55.000	62.000	12.000	63.700
10.000	54.000	64.000	11.000	63.500
10.000	54.000	67.000	13.000	63.500
10.000	54.000	69.000	16.000	63.500
10.000	55.000	75.000	14.000	64.000
10.000	55.000	80.000	8.000	64.200
9.000	51.000	90.000	12.000	64.000
5.000	47.000	74.000	9.000	63.500
.000	43.000	73.000	6.000	63.000
.000	35.000	85.000	4.000	63.000
5.000	33.000	92.000	4.000	62.700
.000	34.000	96.000	4.000	63.000
2.000	48.000	66.000	4.000	63.500
5.000	53.000	45.000	6.000	63.200
4.000	54.000	42.000	7.000	62.700
3.000	44.000	71.000	5.000	62.500
.000	38.000	86.000	5.000	62.200
.000	35.000	89.000	4.000	62.200
.000	34.000	92.000	4.000	62.000
10.000	41.000	86.000	10.000	61.700
10.000	44.000	80.000	7.000	61.500
10.000	48.000	93.000	12.000	61.500
10.000	51.000	93.000	23.000	61.500
10.000	54.000	100.000	17.000	61.000
10.000	57.000	100.000	10.000	61.000
9.000	58.000	100.000	8.000	60.700

7.000	56.000	100.000	3.000	60.700
10.000	53.000	100.000	3.000	61.000
1.000	61.000	97.000	9.000	61.500
10.000	64.000	75.000	6.000	62.000
10.000	57.000	93.000	7.000	61.500
10.000	55.000	96.000	6.000	61.500
10.000	52.000	100.000	8.000	61.200
10.000	50.000	100.000	8.000	61.200
10.000	50.000	100.000	7.000	61.200
10.000	50.000	100.000	6.000	61.000
10.000	50.000	100.000	7.000	60.500
10.000	51.000	100.000	7.000	60.000
10.000	53.000	100.000	4.000	59.500
10.000	53.000	100.000	4.000	59.200
5.000	50.000	93.000	6.000	59.500
7.000	9.000	93.000	4.000	59.500
.000	46.000	89.000	4.000	59.500
1.000	43.000	100.000	3.000	60.000
3.000	56.000	78.000	7.000	60.700
3.000	63.000	65.000	10.000	60.700
7.000	65.000	59.000	10.000	60.000
8.000	54.000	83.000	7.000	59.500
4.000	50.000	89.000	5.000	59.200
.000	47.000	96.000	5.000	59.000
.000	44.000	96.000	3.000	59.000
8.000	45.000	100.000	4.000	58.700
2.000	60.000	87.000	14.000	59.200
7.000	66.000	68.000	12.000	59.500
7.000	68.000	63.000	10.000	59.000

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      .000      61.000      78.000       6.000      59.000
     4.000      61.000      78.000       7.000      58.700
UA=   7718.000R  WIDTH=     400.000CLD  COVER=       2.000TEMP  AIR=      62.000
TEMP WATER=      60.000REL  HUM=       72.000WIND   SPEED=       8.700
NUMBER OF CASES=     4
ALLOWED DTS
  .1000000E 01
  .2000000E 01
  .3000000E 01
  .4000000E 01
NUMBER OF DAYS AVERAGED=      2
DAYS AVERAGED
    1
    2
FTBL1     TTBL1     HFGTB1
**********************************************************************
.885E-01  .320E 02  .108E 04
.122E 00  .400E 02  .107E 04
.176E 00  .500E 02  .107E 04
.256E 00  .600E 02  .106E 04
.363E 00  .700E 02  .105E 04
.507E 00  .800E 02  .105E 04
.698E 00  .900E 02  .104E 04
.949E 00  .100E 03  .104E 04
.127E 01  .110E 03  .103E 04
.169E 01  .120E 03  .103E 04
DAYS SINCE MARCH 21=       75.000BETA=       45.000
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OCTOBER 30 , 1974
OCTOBER 1 to 3 , 17 to 24, and 27 to 29, 1973

NUMBER OF DATA LINES= 112 TIME AV. LOGIC= 0

CLD COVER	AIRTEMP	REL HUM	WIND SPD	WATER TEMP
.000	38.000	96.000	4.000	60.000
.000	37.000	100.000	3.000	60.000
.000	38.000	100.000	3.000	60.000
.000	56.000	72.000	6.000	60.700
3.000	65.000	47.000	8.000	61.000
8.000	66.000	37.000	8.000	60.700
5.000	59.000	56.000	9.000	60.500
5.000	55.000	67.000	5.000	60.500
5.000	54.000	75.000	11.000	60.200
3.000	54.000	75.000	7.000	60.200
10.000	53.000	74.000	9.000	60.200
10.000	58.000	72.000	10.000	60.500
10.000	60.000	84.000	10.000	60.500
10.000	58.000	96.000	9.000	60.700
10.000	58.000	100.000	8.000	60.500
10.000	59.000	97.000	7.000	60.500
10.000	61.000	97.000	8.000	60.500
10.000	60.000	100.000	4.000	60.500
10.000	62.000	100.000	4.000	60.500
10.000	65.000	97.000	6.000	60.700
10.000	64.000	100.000	7.000	61.000
10.000	65.000	100.000	3.000	60.700
10.000	62.000	100.000	5.000	60.500
10.000	58.000	100.000	3.000	60.500
10.000	44.000	65.000	9.000	54.700
10.000	45.000	65.000	6.000	54.700

10.000	45.000	68.000	10.000	54.500
10.000	45.000	77.000	10.000	54.700
10.000	45.000	80.000	14.000	55.000
10.000	47.000	56.000	10.000	55.500
10.000	45.000	58.000	7.000	55.500
10.000	45.000	60.000	7.000	55.500
10.000	43.000	73.000	4.000	55.000
10.000	42.000	76.000	4.000	55.000
9.000	38.000	82.000	5.000	54.700
8.000	46.000	66.000	7.000	54.700
10.000	47.000	61.000	6.000	54.500
10.000	46.000	66.000	6.000	54.500
10.000	45.000	71.000	4.000	54.200
10.000	43.000	73.000	3.000	54.200
1.000	37.000	89.000	3.000	54.000
3.000	32.000	96.000	3.000	54.000
5.000	32.000	100.000	3.000	53.700
1.000	43.000	100.000	.000	53.700
5.000	48.000	63.000	3.000	53.700
10.000	50.000	50.000	5.000	54.200
10.000	44.000	68.000	6.000	54.000
10.000	45.000	58.000	8.000	54.000
10.000	44.000	80.000	11.000	53.700
10.000	44.000	86.000	11.000	53.500
10.000	44.000	86.000	7.000	53.200
10.000	44.000	100.000	3.000	53.000
10.000	46.000	100.000	6.000	53.000
10.000	46.000	100.000	7.000	53.500

10.000	46.000	96.000	10.000	53.200
10.000	44.000	100.000	7.000	53.000
10.000	44.000	100.000	6.000	53.000
9.000	41.000	100.000	7.000	52.700
8.000	39.000	89.000	6.000	52.500
2.000	43.000	71.000	9.000	52.200
.000	47.000	56.000	4.000	52.700
.000	49.000	50.000	4.000	53.200
.000	40.000	86.000	3.000	53.000
.000	37.000	89.000	3.000	52.700
.000	34.000	92.000	5.000	52.500
.000	33.000	96.000	4.000	52.200
4.000	32.000	100.000	3.000	52.000
.000	47.000	93.000	10.000	52.000
3.000	56.000	64.000	6.000	52.000
5.000	58.000	60.000	7.000	52.500
.000	45.000	93.000	5.000	52.500
.000	44.000	86.000	5.000	52.500
.000	40.000	96.000	3.000	52.000
.000	38.000	100.000	3.000	52.000
.000	35.000	100.000	5.000	51.500
4.000	56.000	72.000	11.000	51.700
3.000	62.000	58.000	10.000	52.000
7.000	63.000	54.000	6.000	52.500
8.000	55.000	69.000	5.000	52.500
4.000	50.000	86.000	3.000	52.200
5.000	47.000	93.000	3.000	52.000
5.000	44.000	96.000	3.000	51.500
4.000	39.000	96.000	3.000	51.200

7.000	50.000	96.000	3.000	51.000
4.000	61.000	67.000	6.000	51.500
.000	62.000	67.000	5.000	52.000
.000	52.000	93.000	3.000	52.000
.000	43.000	100.000	3.000	52.000
10.000	54.000	96.000	10.000	52.000
10.000	47.000	96.000	9.000	51.700
10.000	45.000	83.000	10.000	51.500
10.000	44.000	80.000	11.000	51.700
10.000	44.000	74.000	13.000	52.000
10.000	44.000	71.000	9.000	52.000
10.000	40.000	76.000	7.000	51.700
4.000	38.000	67.000	3.000	51.500
2.000	31.000	92.000	3.000	51.000
5.000	30.000	96.000	3.000	51.000
8.000	27.000	96.000	5.000	50.700
8.000	39.000	79.000	4.000	50.500
10.000	42.000	63.000	8.000	50.700
9.000	43.000	63.000	5.000	50.700
10.000	37.000	82.000	3.000	50.500
10.000	41.000	73.000	6.000	50.200
10.000	42.000	71.000	9.000	50.000
8.000	40.000	62.000	12.000	50.000
5.000	36.000	79.000	3.000	50.000
8.000	45.000	68.000	11.000	50.000
10.000	49.000	59.000	12.000	50.000
10.000	43.000	59.000	13.000	50.000
10.000	47.000	74.000	11.000	50.000

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     10.000      47.000      93.000       8.000      50.000

UA=    6240.000R  WIDTH=     400.000CLD  COVER=       1.000TEMP  AIR=      45.000

TEMP WATER=      50.000REL  HUM=      68.000WIND   SPEED=         .000

NUMBER OF CASES=     4

ALLOWED DTS

   .100000E 01

   .200000E 01

   .300000E 01

   .400000E 01

NUMBER OF DAYS AVERAGED=      2

DAYS AVERAGED

     1

     2

PTBL1     TTBL1     HFGTB1

*************************************************************
.885E-01   .320E 02   .108E 04
.122E 00   .400E 02   .107E 04
.178E 00   .500E 02   .107E 04
.256E 00   .600E 02   .106E 04
.363E 00   .700E 02   .105E 04
.507E 00   .800E 02   .105E 04
.698E 00   .900E 02   .104E 04
.949E 00   .100E 03   .104E 04
.127E 01   .110E 03   .103E 04
.169E 01   .120E 03   .103E 04

DAYS SINCE MARCH 21=      108.000BETA=       45.000
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ADDITIONAL DATA FOR STATION 7 ABOVE THE DAM

TEMPERATURES AT STATION 7, ^{O}F, DAILY AVERAGES,
OCTOBER 1-3, 17-24, AND 27-29

60.4, 60.0, 59.8, 55.8, 55.0, 54.5, 53.6, 53.4,
53.0, 52.6, 52.9, 52.7, 51.9, 51.0

NOVEMBER 15, 1973
OCTOBER 17 to 24 and 27 to 29, 1973
NOVEMBER 1 to 14, 1973

NUMBER OF DATA LINES= 200TIME AV. LOGIC= 0

CLD COVER	AIRTEMP	REL HUM	WIND SPD	WATER TEMP
10.000	44.000	65.000	9.000	54.700
10.000	45.000	65.000	6.000	54.700
10.000	45.000	68.000	10.000	54.500
10.000	45.000	77.000	10.000	54.700
10.000	45.000	80.000	14.000	55.000
10.000	47.000	56.000	10.000	55.500
10.000	45.000	58.000	7.000	55.500
10.000	45.000	60.000	7.000	55.500
10.000	43.000	73.000	4.000	55.000
10.000	42.000	76.000	4.000	55.000
9.000	38.000	82.000	5.000	54.700
8.000	46.000	66.000	7.000	54.700
10.000	47.000	61.000	6.000	54.500
10.000	46.000	66.000	6.000	54.500
10.000	45.000	71.000	4.000	54.200
10.000	43.000	73.000	3.000	54.200
1.000	37.000	89.000	3.000	54.000
3.000	32.000	96.000	3.000	54.000
5.000	32.000	100.000	3.000	53.700
1.000	43.000	100.000	.000	53.700
5.000	48.000	63.000	3.000	53.700
10.000	50.000	50.000	5.000	54.200
10.000	44.000	68.000	6.000	54.000
10.000	45.000	58.000	8.000	54.000
10.000	44.000	80.000	11.000	53.700
10.000	44.000	86.000	11.000	53.500

10.000	44.000	86.000	7.000	53.200
10.000	44.000	100.000	3.000	53.000
10.000	46.000	100.000	6.000	53.000
10.000	46.000	100.000	7.000	53.500
10.000	46.000	96.000	10.000	53.200
10.000	44.000	100.000	7.000	53.000
10.000	44.000	100.000	6.000	53.000
9.000	41.000	100.000	7.000	52.700
8.000	39.000	89.000	6.000	52.500
2.000	43.000	71.000	9.000	52.200
.000	47.000	56.000	4.000	52.700
.000	49.000	50.000	4.000	53.200
.000	40.000	86.000	3.000	53.000
.000	37.000	89.000	3.000	52.700
.000	34.000	92.000	5.000	52.500
.000	33.000	96.000	4.000	52.200
4.000	32.000	100.000	3.000	52.000
.000	47.000	93.000	10.000	52.000
3.000	56.000	64.000	6.000	52.000
5.000	58.000	60.000	7.000	52.500
.000	45.000	93.000	5.000	52.500
.000	44.000	86.000	5.000	52.500
.000	40.000	96.000	3.000	52.000
.000	38.000	100.000	3.000	52.000
.000	35.000	100.000	5.000	51.500
4.000	56.000	72.000	11.000	51.700
3.000	62.000	58.000	10.000	52.000
7.000	63.000	54.000	6.000	52.500

8.000	55.000	69.000	5.000	52.500
4.000	50.000	86.000	3.000	52.200
5.000	47.000	93.000	3.000	52.000
5.000	44.000	96.000	3.000	51.500
4.000	39.000	96.000	3.000	51.200
7.000	50.000	96.000	3.000	51.000
4.000	61.000	67.000	6.000	51.500
.000	62.000	67.000	5.000	52.000
.000	52.000	33.000	3.000	52.000
.000	43.000	100.000	3.000	52.000
10.000	54.000	96.000	10.000	52.000
10.000	47.000	96.000	9.000	51.700
10.000	45.000	83.000	10.000	51.500
10.000	44.000	80.000	11.000	51.700
10.000	44.000	74.000	13.000	52.000
10.000	44.000	71.000	9.000	52.000
10.000	40.000	76.000	7.000	51.700
4.000	38.000	67.000	3.000	51.500
2.000	31.000	92.000	3.000	51.000
5.000	30.000	96.000	3.000	51.000
8.000	27.000	96.000	5.000	50.700
8.000	39.000	79.000	4.000	50.500
10.000	42.000	63.000	8.000	50.700
9.000	43.000	63.000	5.000	50.700
10.000	37.000	82.000	3.000	50.500
10.000	41.000	73.000	6.000	50.200
10.000	42.000	71.000	9.000	50.000
8.000	40.000	62.000	12.000	50.000
5.000	36.000	79.000	3.000	50.000

8.000	45.000	68.000	11.000	50.000
10.000	49.000	59.000	12.000	50.000
10.000	49.000	59.000	13.000	50.000
10.000	47.000	74.000	11.000	50.000
10.000	47.000	93.000	8.000	50.000
10.000	39.000	93.000	3.000	49.000
10.000	48.000	80.000	5.000	49.000
10.000	46.000	83.000	6.000	49.000
10.000	47.000	93.000	6.000	49.000
10.000	49.000	93.000	9.000	49.200
10.000	50.000	69.000	12.000	50.000
10.000	49.000	63.000	14.000	50.000
10.000	49.000	61.000	20.000	49.200
10.000	49.000	56.000	13.000	49.000
6.000	49.000	50.000	14.000	48.200
4.000	48.000	48.000	16.000	48.200
5.000	49.000	48.000	8.000	48.500
8.000	54.000	43.000	9.000	48.700
10.000	52.000	45.000	9.000	48.700
10.000	50.000	50.000	5.000	48.500
10.000	45.000	74.000	5.000	48.500
10.000	43.000	76.000	6.000	48.700
3.000	42.000	71.000	14.000	48.700
3.000	42.000	60.000	14.000	49.000
3.000	44.000	47.000	15.000	49.000
9.000	44.000	40.000	17.000	49.200
9.000	42.000	41.000	12.000	49.000
4.000	41.000	40.000	15.000	49.000

9.000	40.000	39.000	14.000	48.500
9.000	39.000	38.000	18.000	48.500
6.000	37.000	39.000	12.000	48.500
8.000	36.000	40.000	14.000	48.200
9.000	36.000	40.000	17.000	48.200
9.000	38.000	37.000	11.000	48.200
6.000	39.000	36.000	11.000	48.200
9.000	37.000	41.000	8.000	47.500
1.000	33.000	44.000	8.000	47.000
2.000	31.000	47.000	6.000	47.000
2.000	32.000	43.000	7.000	46.700
3.000	31.000	43.000	7.000	46.700
5.000	34.000	42.000	12.000	47.000
9.000	35.000	37.000	9.000	47.000
6.000	38.000	31.000	10.000	46.700
5.000	35.000	32.000	11.000	46.500
8.000	34.000	37.000	7.000	45.700
10.000	32.000	33.000	11.000	45.500
10.000	31.000	36.000	10.000	45.200
10.000	30.000	41.000	12.000	45.000
7.000	28.000	53.000	14.000	45.000
9.000	31.000	40.000	10.000	45.000
10.000	32.000	38.000	17.000	45.000
10.000	29.000	58.000	8.000	44.700
10.000	28.000	61.000	12.000	44.500
7.000	27.000	55.000	7.000	44.500
7.000	25.000	60.000	9.000	44.500
8.000	27.000	61.000	5.000	44.500
8.000	30.000	58.000	4.000	44.500

7.000	36.000	52.000	6.000	44.700
9.000	38.000	46.000	12.000	44.700
9.000	38.000	46.000	10.000	44.200
10.000	38.000	53.000	7.000	44.000
10.000	36.000	57.000	8.000	44.000
10.000	36.000	62.000	7.000	44.000
10.000	36.000	62.000	10.000	43.500
10.000	36.000	57.000	15.000	43.500
10.000	38.000	50.000	15.000	43.500
9.000	40.000	45.000	14.000	43.500
10.000	41.000	45.000	13.000	43.500
7.000	38.000	57.000	8.000	43.500
9.000	36.000	42.000	12.000	43.200
9.000	35.000	42.000	7.000	43.000
6.000	32.000	45.000	7.000	43.000
7.000	32.000	43.000	12.000	43.000
7.000	34.000	38.000	12.000	43.000
9.000	33.000	45.000	12.000	43.000
9.000	31.000	43.000	15.000	42.500
10.000	29.000	45.000	13.000	42.200
9.000	26.000	46.000	14.000	42.000
10.000	25.000	46.000	12.000	41.700
10.000	25.000	53.000	12.000	41.500
10.000	25.000	66.000	10.000	41.500
8.000	30.000	56.000	9.000	41.500
7.000	33.000	42.000	9.000	41.200
5.000	31.000	43.000	10.000	41.200
10.000	31.000	45.000	11.000	41.000

10.000	29.000	51.000	6.000	41.000
10.000	27.000	55.000	6.000	41.000
9.000	27.000	53.000	6.000	41.000
8.000	29.000	49.000	9.000	41.000
8.000	33.000	48.000	4.000	42.000
10.000	36.000	42.000	7.000	42.000
10.000	34.000	44.000	6.000	41.500
10.000	33.000	50.000	.000	41.200
10.000	34.000	52.000	7.000	41.200
10.000	34.000	64.000	7.000	41.200
10.000	35.000	59.000	10.000	41.200
10.000	37.000	59.000	12.000	41.500
10.000	39.000	53.000	14.000	41.500
10.000	39.000	51.000	15.000	41.500
10.000	39.000	48.000	14.000	41.500
10.000	41.000	43.000	14.000	41.500
10.000	41.000	43.000	13.000	41.500
10.000	41.000	43.000	13.000	41.500
10.000	41.000	45.000	10.000	41.500
10.000	43.000	47.000	13.000	41.500
10.000	45.000	49.000	10.000	41.500
10.000	46.000	50.000	8.000	41.500
10.000	46.000	52.000	5.000	41.500
10.000	46.000	52.000	8.000	41.500
10.000	48.000	48.000	13.000	41.500
10.000	51.000	48.000	14.000	41.500
10.000	54.000	51.000	14.000	41.500
10.000	55.000	57.000	10.000	41.500
8.000	61.000	46.000	13.000	42.000

```
      8.000      57.000      42.000      12.000      42.000
      6.000      48.000      63.000       4.000      42.000
      8.000      45.000      71.000       4.000      42.000
LA=   7640.000R  WIDTH=     400.000CLD  COVER=       1.000TEMP  AIR=      50.000
TEMP WATER=      41.700REL  HUM=       68.000WIND   SPEED=        4.400
NUMBER OF CASES=     4
ALLOWED DTS
  .100000E 01
  .200000E 01
  .300000E 01
  .400000E 01
NUMBER OF DAYS AVERAGED=      2
DAYS AVERAGED
    1
    2
PTBL1     TTBL1     HFGTB1
**********************************************************
.685E-01  .320E 02  .108E 04
.122E 00  .400E 02  .107E 04
.178E 00  .500E 02  .107E 04
.256E 00  .600E 02  .106E 04
.363E 00  .700E 02  .105E 04
.507E 00  .800E 02  .105E 04
.698E 00  .900E 02  .104E 04
.949E 00  .100E 03  .104E 04
.127E 01  .110E 03  .103E 04
.169E 01  .120E 03  .103E 04
DAYS SINCE MARCH 21=      124.000BETA=       45.000
```

APPENDIX C

PROGRAM LISTINGS

This appendix presents complete program listings for the STREAM, SENSIT, and MONT codes.

```
C
C
C     STREAM
C
C
C     STREAM THERMAL MODEL
C
C
      COMMON DTEMP,TEMP,XPR,XEND,DXPR,X,DX, INT,INTC,IN,IO,EL,AREA,U
      COMMON FRACR,DXMAX
      COMMON/RHO/ RMO,HO,TAIR,CLD,RH,ALBAR,TMS,TA, EM,EA,HOS,HS
      COMMON HSR,HRB,FBR,EVAP,HE,HC,HI YMN,PTBL(10),TTBL(10),WMS,CONST
      COMMON  HFG,CLD1,HFGTB(10),CONS1
      IN=5
      IO=6
      CALL INPUT
      IF(INTC - 4) 4,105,105
4     XPR = DXPR
5     CONTINUE
      DO 100 JE= 1,INT
      CALL DIFFQ
      GO TO (10,10,20), INTC
10    CALL EULER(DTEMP,TEMP,DX,1,JE,X)
      GO TO 100
20    CALL RK4(DTEMP,TEMP,DX,1,JE,X)
100   CONTINUE
      IF(X - XPR )        5,250,250
250   CALL OUT
```

```
      XPR = XPR + DXPR
      IF(X - XEND) 5,300,300
105   CONTINUE
      JUMP = -1
110   CONTINUE
      XPR = X + DXPR
120   CONTINUE
      CALL SRD(DTEMP,X,XPR,TEMP,ERRSR,1.D-6,DX,DXMAX,JUMP,KSTP,KC,1.E-6,I8)
      IF(JUMP)130,140,150
130   WRITE(19,131) X
131   FORMAT(//'    X ='E14.5'  INTEGRATION FAILURE!)
      CALL EXIT
140   CONTINUE
      CALL DIFFQ
      GO TO 120
150   CALL OUPT
      IF(X - XEND) 110,300,300
300   CALL EXIT
      END
      SUBROUTINE INPUT
      COMMON DTEMP,TEMP,  XPR,XEND,DXPR,X,DX, INT,INTC,
     1 IN,IO,FI ,ANEA, J,ERRSR,DXMAX
      COMMON WRHO, WMD,HD,TAIR,CLD,RH,ALBAR,TWS,TA, EW,EA,HBS,HS
      COMMON HSR,HBB,FBR,EVAP,HE,HC,HLYMN,PTBL(10) ,TTBL(10) ,WMS,CONST
      COMMON  HFG,CLD1,HFGTB(10),CONS1
10    FORMAT(6F10.0)
20    FORMAT(6I10)
C     CHOICE OF INTEGRATION SUBROUTINE
```

```
57.000        READ(IN,90)     INTC
58.000        IF(INTC - 3) 30,40,50
59.000 30     INT = INTC
60.000        GO TO 60
61.000 40     INT = 4
62.000        GO TO 60
63.000 50     CONTINUE
64.000 60     CONTINUE
65.000        GO TO (110,120,130,140), INTC
66.000 110    WRITE(10,115)
67.000 115    FORMAT('1     ****   EULER INTEGRATION    *****'//)
68.000        GO TO 150
69.000 120    CONTINUE
70.000        WRITE(10,125)
71.000 125    FORMAT('1     *****  MOD. EULER INTEGRATION  *****'//)
72.000         GO TO 150
73.000 130    WRITE(10,135)
74.000 135    FORMAT('1     *****  4 TH ORDER  RUNGE-KUTTA   ******'//)
75.000         GO TO 150
76.000 140    WRITE(10,145)
77.000 145    FORMAT('1     *****   ADAMS MOULTON INTEG.  *******'//)
78.000 150    CONTINUE
79.000 C
80.000 C      INTEGRATION CONTROL PARAMETERS
81.000        READ(IN,10) X,DX,DXPR,XEND
82.000        WRITE(10,160)X,DX,DXPR,XEND
83.000 160    FORMAT('  X =',F4.2,'    DX =',E10.3,'    DXPR =',E10.3
84.000       1 '    XEND =',E10.3,/)
85.000        READ(IN,10) ERROR,DXMAX
```

```
      WRITE(IO,180) ERROR,DXMAX
180   FORMAT('   ERROR =',E10.3,'   DXMAX =',E:0.3,/)
      READ(IN,10) TEMP,U,AREA,EL
      READ(IN,10) RHO,WMPH,TAIR,CLD,RH,ALBAR
      DO 185 I=1,10
185   READ(IN,10) PTBL(I), TTBL(I), HEGTB(I)
      TA = (TAIR - 32.)*5./9.
      W = WMPH*22./15.
      WMS = W * .3048
      WMD = WMPH * 24.
      CONST = EL/(RHO*U*AREA)
      CONS1 = (RHO*0.00328)/(24.*3600.*0.06:4)
      SINA = SIN(ALBAR*3.14159/180.)
      CLD1 = 1. - .0765*CLD
C     INCIDENT SOLAR RADIATION
      HOS = 1.9*SINA
      HS = HOS*(1. - .0006*CLD**3)
C     REFLECTED SOLAR RADIATION
      HSR = HS*3./ALBAR
      EA = RH*(1013./1470.)*SI(TTBL,PTBL,TAIR,10)
      WRITE(IO,200) TEMP
200   FORMAT('  INITIAL STREAM TEMPERATURE =',F6.2,'  DEG F'/)
      WRITE(IO,210) U,AREA,EL
210   FORMAT('  STREAM VELOCITY =',F6.3,' FT/SEC   CR. SEC. AREA ='
     1F10.2,'  SQ. FT.      SURFACE WIDTH =',F6.1,'  FT'/)
      WRITE(IO,220) RHO,CLD,RH,ALBAR
220   FORMAT('  RHO =',F5.2,'  LB/CU.FT.       CLD =',F4.1,'  TENTHS',
     1'    RH =',F5.1,'  PCT'/'  ALBAR =',F4.1,'  DEGREES'/)
```

```
      WRITE(19,230) TAIR,TA,CONST, CONS1
  230 FORMAT('  AIR TEMP. ='F5.1' DEG F'F8.1'  DEG C',
     1'     CONST ='E10.3'      CONS1 ='E10.3'/')
      WRITE(19,240) V,VMPH,VMS,VMD
  240 FORMAT('  WIND VELOCITY ='F6.2' FT/SEC'F8.2'MPH'F8.2' METERS',
     1'/SEC'F8.2'  MILES/DAY'/)
      WRITE(19,260)
  260 FORMAT(/,T20'TTAL'T40'PTAL'T60'HFGTB'/)
      DO 270 I =1,10
  270 WRITE(19,280) TTBL(I), PTBL(I), HFGTB(I)
  280 FORMAT(10X,3F20.5)
      WRITE(19,300) EA,HMS,HS,HSR
  300 FORMAT(//'  EA ='E12.4'     HBS ='F12.4'    HS ='E12.4,
     1 '    HSR ='E12.4'  LY/MIN')
      WRITE(19,310)
  310 FORMAT('1')
      RETURN
      END
      SUBROUTINE OUPT
      COMMON DTEMP, TEMP,        XPR,XEND,DXPR,X,DX, INT,INTC,
     1 IN,I9,FI,AREA,U,ERROR,DXMAX
      COMMON VRMB,VMD,HD,TAIR,CLD,RH,ALBAR,TAS,TA, EA,EA,HBS,HS
      COMMON HSR,HBB,FBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),VMS,CONST
      COMMON  HFG,CLD1,HFGTB(10),CONS1
      WRITE(19,10) X,DX
   10 FORMAT('    X ='F7.1' FT      DX ='FA.1, /)
      WRITE(19,20) TEMP,DTEMP
   20 FORMAT('  STREAM TEMP ='F6.2' DEG F         DTEMP ='E10.3,
     1'  DEG F/FT'/)
```

```
143.000          WRITE(I9,30) EW, EVAP,HF,HFG
144.000 30       FORMAT('  EW =',F12.5,
145.000         1E12.5,'  LY/MIN    HFG =',E12.5,/)                    EVAP,MMPD =',E12.5,' HE =',
146.000          WRITE(I9,50) H9R,FBR,HC
147.000 50       FORMAT('  H9R =',E12.5,'   EBR=',E12.5,'   HC  =',E12.5,'  LY/MIN',/)
148.000          WRITE(I9,60) HLYMN,HD
149.000 60       FORMAT('  TOTAL HEAT TRANSFER =',E12.5,'  LY/MIN',E15.5,
150.000         1'   BTJ/SEC-FT2',/)
151.000          WRITE(I9,70)
152.000 70       FORMAT(////)
153.000          RETURN
154.000          END
155.000          SUBROUTINE DIFEQ
156.000          COMMON/TEMP,  TEMP,          XPR,XEND,DXPR,X,DX,  INT,INTC,
157.000         1 IN,I9,FI ,AREA, I,ERROR,DXMAX
158.000          COMMON/RMB, WMD,HD,TAIR,CLD,RH,ALBAR,TWS,TA, EW,EA,H0S,HS
159.000          COMMON HSR,H0B,FBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CONST
160.000          COMMON  HFG,CLD1,HFGTB(10),CONS1
161.000 C        THERMAL EXCHANGE WITH ENVIRONMENT.
162.000          TWS= (TEMP-32.)*5./9.
163.000          EW=(1013./14.7)*SI(TTBL,PTBL,TEMP,10)
164.000 C        EFFECTIVE BACK RADIATION.
165.000          H0B= (14.38-.09*TWS-.046*RH)/69.72
166.000          EBR = H0B * CLD1
167.000 C        EVAPORATION HEAT TRANSFER.
168.000          EVAP = .35* (EW-EA)*(1. + .009*WMD)
169.000          HFG = SI(TTBL,HFGTB,TEMP,10)
170.000          HE = EVAP*HFG*CONS1
```

```
C     CONVECTION HEAT TRANSFER
      HC = 39.*(.26 + .077*WMS)*(TWS - TA )/1440.
C     TOTAL HEAT TRANSFER TO WATER, LY/MIN
      HLYMN = HS - (EBR + HSR + HC + HE)
C     TOTAL HEAT TRANSFER, BTU/SEC-FT2
      HD = HLYMN * .0414
C     DERIVATIVE CALCULATION
      DTEMP = CONST*HD
      RETURN
      END
CCCCC
CCCCC
CCCCC
CCCCC
      FUNCTION SI(XTBL,YTBL,X,N)
C     LINEAR INTERPOLATION OR EXTRAPOLATION OF SINGLE VARIABLE FUNCTION
C     XTBL = INDEPENDENT VARIABLE TABLE
C     YTBL = DEPENDENT VARIABLE TABLE
C     IND = INDICATOR OF EXTRAPOLATION
C     0=NO EXTRAPOLATION, 1=LOWER EXTRAPOLATION, 2=UPPER EXTRAPOLATION
      DIMENSION XTBL(40),YTBL(40)
C     CHECK TO SEE IF EXTRAPOLATION IS NEEDED.
      IF(X-XTBL(1)) 120,130,150
  120 IND = 1
  130 II = 2
      GO TO 200
  150 IF(XTBL(N)-X) 160,180,210
  160  IND = 2
  180  II = N
```

```
200.000          GO TO 254
201.000 C        FIND X IN TABLE.S IN TABLE
202.000    210   DO 220 IK=2,N
203.000          II = IK
204.000          IF(XTBL(IK)-X) 220,254,254
205.000    220   CONTINUE
206.000    254   X1 = XTBL(II-1)
207.000          X2 = XTBL(II)
208.000          Y1 = YTBL(II-1)
209.000          Y2 = YTBL(II)
210.000          SI = Y1+(Y2-Y1)*(X-X1)/(X2-X1)
211.000          RETURN
212.000          END
213.000 CCCCC
214.000 CCCCC
215.000 C        EULER AND MODIFIED EULER INTEGRATION
216.000 CCCCC
217.000 CCCCC
218.000 CCCCC
219.000          SUBROUTINE EULER(YP,Y,DT,NE,J,T)
220.000          DIMENSION YP(20),Y(20), SY(20),SYP(20)
221.000          GO TO(10,20),J
222.000    10    CONTINUE
223.000          DO 100 I=1,NE
224.000          SY(I)= Y(I)
225.000          SYP(I)= YP(I)
226.000          Y(I)= Y(I)+DT*YP(I)
227.000    100   CONTINUE
```

```
228.000         T=T+DT
229.000         RETURN
230.000      20 CONTINUE
231.000         DO 200 I=1,NE
232.000         Y(I)= SY(I)+(YP(I)+SYP(I))*DT/2.
233.000     200 CONTINUE
234.000         RETURN
235.000         END
236.000 CCCCC
237.000 CCCCC
238.000 CCCCC
239.000 C       FOURTH ORDER RUNGE-KUTTA INTEGRATION
240.000 CCCCC
241.000 CCCCC
242.000 CCCCC
243.000         SUBROUTINE RK4(YP,Y,DT,NE,J,T)
244.000         DIMENSION YP(5),Y(5),AK(5,4),SY(5)
245.000         GO TO(10,20,30,40),J
246.000 10      CONTINUE
247.000         DO 100 I=1,NE
248.000         SY(I) = Y(I)
249.000         AK(I,1) = DT*YP(I)
250.000         Y(I) = Y(I) +AK(I,1)*.5
251.000 100     CONTINUE
252.000         ST = T
253.000         T = T + DT*.5
254.000         RETURN
255.000 20      CONTINUE
256.000         DO 200 I=1,NE
```

```
      AK(I,2) = DT*YP(I)
      Y(I) = SY(I) + AK(I,2)*.5
200   CONTINUE
      RETURN
30    CONTINUE
      DO 300 I = 1,NE
      AK(I,3) = DT*YP(I)
      Y(I) = SY (I) + AK(I,3)
300   CONTINUE
      T = ST + DT
      RETURN
40    CONTINUE
      DO 400 I = 1,NE
      AK(I,4) = DT *YP(I)
      Y(I)=SY(I)+(AK(I,1)+AK(I,4)+2.*(AK(I,2)+AK(I,3)))/6.
400   CONTINUE
      RETURN
      END
CCCCC
CCCCC
CCCCC
C     ADAMS-MOULTON INTEGRATION
CCCCC
CCCCC
CCCCC
      SUBROUTINE ADAM(F,T,TLIM,Y,ERROR,NE,H,HMAX,JUMP,KSTP,KCON,CLIF,I0)
      DIMENSION STARY(5),Y(5),SY(5),SAVFY(5),F(5),FP(5),DELTA(5),DALTA(5
     1),A(5),B(5),C(5),D(5),AA(5),BB(5),CC(5),DD(5),SF(5)
```

```
285.000         IF(KSTP-32767)993,99,991
286.000    991  KSTP=28
287.000 C       TEST FOR TYPE OF ENTRY
288.000    993  IF(JUMP)11,998,999
289.000    998  GO TO (1000,11,21,802,803),IA
290.000 C       JUMP POS.     RESTORE VALUES
291.000    999  T=SAVET
292.000    992  JUMP=0
293.000         DO 901 I=1,NF
294.000         F(I)=SF(I)
295.000    901  Y(I)=SAVEY(I)
296.000         GO TO 102
297.000 C       JUMP NEG.     INITIALIZE
298.000      1  DO 5 I=1,NE
299.000         STARY(I)=Y(I)
300.000         A(I)=0.001
301.000         B(I)=0.001
302.000         C(I)=0.001
303.000      5  D(I)=0.001
304.000         KSTP=0
305.000         KDELY=0
306.000         KCON=0
307.000         XT=95./(288.*64.)
308.000         U=863./(12.*5040.)
309.000         V=95.0/288.0
310.000         P=25.0/24.0
311.000         Q=35.0/72.0
312.000         R=5.0/48.0
313.000         S=1.0/120.0
```

```
      IA=1
      JUMP=0
      GO TO 1101
C     BEGIN INTEGRATION STEP
 1000 DO 1111 I=1,NE
      SF(I)=F(I)
 1111 SAVEY(I)=Y(I)
C     H TOO SMALL  RETURN WITH JUMP NEG.
  600 IF(ABS(T+H)-ABS(T))605,601,605
  601 JUMP=-1
      GO TO 1101
  605 T=T+H
      DO 10 I=1,NE
      Y(I)=Y(I)+H*(F(I)+A(I)+B(I)+C(I)+D(I))
   10 FP(I)=F(I)+2.0*A(I)+3.0*B(I)+4.0*C(I)+5.0*D(I)
      IA=2
      GO TO 1101
   11 DO 12 I=1,NE
   12 SY(I)=Y(I)
      DO 20 I=1,NE
      DELTA  (I)=F(I)-FP(I)
   20 Y(I)=Y(I)+V*DELTA  (I)*H
      IA=3
      KODE=1
      GO TO 1101
   21 KODE=0
      DO 30 I=1,NE
      DALTA  (I)=F(I)-FP(I)
```

```
342.000     29 Y(I)=SY(I)+V*DALTA  (I)*H
343.000     30 CONTINUE
344.000 C      TEST FOR STARTING SEQUENCE
345.000     31 IF(KSTP-28)35,40,40
346.000 C      APPLY TEST 2 ON ZEROTH STEP
347.000     35 IF(KSTP)50,50,60
348.000 C      HALVING TESTS
349.000     40 DO 45 I=1,NE
350.000        IF(ABS(DALTA  (I))-ERROR/ABS(H))45,45,55
351.000     45 CONTINUE
352.000     50 IF(V*H*CI.IF-0.125)60,60,55
353.000     55 T=T-H
354.000 C      FAIL TESTS, HALVE H
355.000    223 H=H/2.0
356.000        KOELY=0
357.000        DO 56 I=1,NE
358.000        A(I)=A(I)/2.0
359.000        B(I)=B(I)/4.0
360.000        C(I)=C(I)/8.0
361.000        F(I)=SF(I)
362.000        Y(I)=SAVEY(I)
363.000     56 D(I)=D(I)/16.0
364.000        GO TO 1000
365.000 C      PASS TESTS, CORRECT A,B,C,D
366.000     60 KSTp=KSTp+1
367.000        DO 65 I=1,NE
368.000        A(I)=A(I)+3.0*B(I)+6.0*C(I)+10.0*D(I)+P*DALTA  (I)
369.000     62 B(I)=B(I)+4.0*C(I)+10.0*D(I)+Q*DALTA(I)
370.000     64 C(I)=C(I)+5.0*D(I)+R*DALTA(I)
```

```
371.000      67 D(I)=D(I)+S*DALTA(I)
372.000      65 CONTINUE
373.000 C       IF IN STARTING SEQUENCE, BRANCH
374.000         IF(KSTP-24)70,90,100
375.000      70 GO TO (1000,1000,1000,74,1000,1000,1000,78,1000,1000,1000,74,1000,
376.000        11000,1000,86,1000,1000,1000,74,1000,1000,1000),KSTP
377.000 C       4TH, 12TH, 20TH STEP, GO BACK
378.000      74 H=-H
379.000         DO 75 I=1,NE
380.000         A(I)=-A(I)
381.000      75 C(I)=-C(I)
382.000         GO TO 1000
383.000 C       8TH STEP  GO FORWARD
384.000      78 H=-H
385.000         DO 79 I=1,NE
386.000         Y(I)=STARY(I)
387.000         A(I)=-A(I)
388.000      79 C(I)=-C(I)
389.000         GO TO 1000
390.000 C       16TH STEP, HALVE H, APPLY TEST 1
391.000      86 H=H/2.0
392.000         DO 87 I=1,NE
393.000         A(I)=A(I)/2.0
394.000         B(I)=B(I)/4.0
395.000         C(I)=C(I)/8.0
396.000      87 D(I)=D(I)/16.0
397.000         DO 88 I=1,NE
398.000         IF(ABS(DALTA  (I))-ERROR/ABS(H))88,88,89
```

```
399.000      88 CONTINUE
400.000 C       PASS TEST   GO FORWARD WITH HALVED H
401.000         GO TO 78
402.000 C       FAIL TEST   BEGIN AGAIN WITH HALVED H
403.000      89 H=-H
404.000         DO 92 I=1,NE
405.000      92 Y(I)=STARY(I)
406.000         GO TO 1
407.000 C       24TH STEP, DOUBLE H, STARTING SEQUENCE ENDS
408.000      90 H=H*2.0
409.000         DO 91 I=1,NE
410.000         A(I)=A(I)*2.0
411.000         B(I)=B(I)*4.0
412.000         C(I)=C(I)*8.0
413.000      91 D(I)=D(I)*16.0
414.000         GO TO 78
415.000     100 KDELY=KDELY+1
416.000 C       WILL NEXT STEP MOVE PAST TLIM
417.000     102 IF(ABS(TLIM-T)-ABS(H))103,103,110
418.000 C       YES.........SAVE T AND Y, INTEGRATE TO TLIM,RETURN.
419.000     103 ENDH=TLIM-T
420.000         DO 105 I=1,NF
421.000         AA(I)=ENDH*A(I)/H
422.000         BB(I)=ENDH**2*B(I)/H**2
423.000         CC(I)=ENDH**3*C(I)/H**3
424.000     105 DD(I)=ENDH**4*D(I)/H**4
425.000         SAVET=T
426.000         DO 800 I=1,NF
427.000         SF(I)=F(I)
```

```
428.000    800 SAVEY(I)=Y(I)
429.000    806 T=TLIM
430.000        DO 106 I=1,NF
431.000        Y(I)=Y(I)+ENDH*(F(I)+AA(I)+BB(I)+CC(I)+DD(I))
432.000    106 FP(I)=F(I)+2.0*AA(I)+3.0*BB(I)+4.0*CC(I)+5.0*DD(I)
433.000        IA=4
434.000        GO TO 1101
435.000    802 DO 805 I=1,NF
436.000    805 SY(I)=Y(I)
437.000        DO 107 I=1,NF
438.000        DELTA  (I)=F(I)-FP(I)
439.000    107 Y(I)=Y(I)+V*DELTA  (I)*ENDH
440.000        IA=5
441.000        GO TO 1101
442.000    803 DO 108 I=1,NF
443.000        DALTA  (I)=F(I)-FP(I)
444.000    108 Y(I)=SY(I)+V*DALTA  (I)*ENDH
445.000        JUMP=1
446.000        GO TO 1101
447.000 C      NO.....TEST FOR DOUBLING. IF OK, BEGIN NEST STEP AFTER DOUBLING
448.000    110 IF(ABS(TLIM-T)-ABS(2.0*H))1000,1000,111
449.000    111 IF(KDELY-4)1000,120,120
450.000    120 IF(ABS(2.0*H)-ABS(HMAX))121,121,1000
451.000    121 DO 125 I=1,NF
452.000        IF(ABS(DALTA  (I))-ERROR/(128.0*ABS(H)))125,125,1000
453.000    125 CONTINUE
454.000        IF(V*H*CLIF-0.0625)130,1000,1000
455.000    130 CONTINUE
```

```
456.000    335 H=2.0*H
457.000        DO 135 I=1,NF
458.000        A(I)=2.0*A(I)
459.000        B(I)=4.0*B(I)
460.000        C(I)=8.0*C(I)
461.000    135 D(I)=16.0*D(I)
462.000        KDELY=0
463.000        GO TO 1000
464.000   1101 CONTINUE
465.000   1150 FORMAT(/,2X,'HH =',2X,F10.6,14X,'KSTP =',2X,I3,10X,'DAL3A(I)',//)
466.000   1151 FORMAT(5(2X,I2,1X,E14.7))
467.000        RETURN
468.000        END
```

```
1.000 C
2.000 C
3.000 C      SENSIT
4.000 C
5.000 C
6.000 C      SENSITIVITY ANALYSIS
7.000 C
8.000 C
9.000 C
10.000       COMMON DDT,DT,XPR,XEND,DXPR,X,DX,INT,INTC,IN,IO,EL,AREA,U
11.000       COMMON ERROR,DXMAX,TEMP,HFGTB(10),CONST
12.000       COMMON RHO,WMD,HD,TAIR,CLD,RH,ALBAR,TWS,TA,EW,EA,HBS,HS
13.000       COMMON HSR,HBB,EBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CONST
14.000       COMMON HFG,HBC,CLD1,CLDP,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
15.000      1DTA,DW,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
16.000       IN=5
17.000       IO=6
18.000       CALL INPUT
19.000       IF(INTC - 4) 4,105,105
20.000 4     XPR = DXPR
21.000 5     CONTINUE
22.000       DO 100 JE= 1,INT
23.000       CALL DIFEQ
24.000       GO TO (10,10,20), INTC
25.000 10    CALL EULER(DDT,DT,DX,1,JE,X)
26.000       GO TO 100
27.000 20    CALL RK4(DDT,DT,DX,1,JE,X)
28.000 100   CONTINUE
29.000       IF(X - XPR )        5,250,250
30.000 250   CALL OUPT
31.000       XPR = XPR + DXPR
32.000       IF(X - XEND) 5,300,300
33.000 105   CONTINUE
34.000       JUMP = -1
35.000 110   CONTINUE
36.000       XPR = X + DXPR
```

```
37.000 120   CONTINUE
38.000       CALL NORD(DDT,X,XPR,DT,ERROR,1,DX,DXMAX,JUMP,KS,KC,1.E-6,IO)
39.000       IF(JUMP)130,140,150
40.000 130   WRITE(IO,131) X
41.000 131   FORMAT(///'    X ='E14.5'  INTEGRATION FAILURE')
42.000       CALL EXIT
43.000 140   CONTINUE
44.000       CALL DIFEQ
45.000       GO TO 120
46.000 150   CALL OUPT
47.000       IF(X - XEND) 110,300,300
48.000 300   CALL EXIT
49.000       END
50.000       SUBROUTINE INPUT
51.000       COMMON DDT,   DT,   XPR,XEND,DXPR,X,DX,INT,INTC,
52.000      1 IN,IO,EL,AREA,J,ERROR,DXMAX,TEMP,HEGTB(10),CONST
53.000       COMMON RHO,WMD,HD,TAIR,CLD,RH,ALBAR,TWS,TA,EW,EA,HOS,HS
54.000       COMMON HSR,HSB,FBR,EVAP,HE,HC,DLYMN,PTBL(10),TTBL(10),WMS,CONST
55.000       COMMON HEG,HBC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
56.000      1DTA,DW,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
57.000 10    FORMAT(6F10.0)
58.000 20    FORMAT(6I10)
59.000       RATIO = 3.14159/180.
60.000 C     CHOICE OF INTEGRATION SUBROUTINE
61.000       READ(IN,20)  INTC
62.000       IF(INTC - 3) 30,40,50
63.000 30    INT = INTC
64.000       GO TO 60
```

```
65.000 40    INT = 4
66.000       GO TO 60
67.000 50    CONTINUE
68.000 60    CONTINUE
69.000       GO TO (110,120,130,140), INTC
70.000 110   WRITE(IO,115)
71.000 115   FORMAT('1     ****   EULER INTEGRATION    ******'//)
72.000       GO TO 150
73.000 120   CONTINUE
74.000       WRITE(IO,125)
75.000 125   FORMAT('1      *****  MOD. EULER INTEGRATION  *****'//)
76.000        GO TO 150
77.000 130   WRITE(IO,135)
78.000 135   FORMAT('1      *****  4 TH ORDER  RUNGE-KUTTA   ******'//)
79.000        GO TO 150
80.000 140   WRITE(IO,145)
81.000 145   FORMAT('1     *****   ADAMS MOULTON INTEG.  *******'//)
82.000 150   CONTINUE
83.000 C
84.000 C     INTEGRATION CONTROL PARAMETERS
85.000       READ(IN,10) X,DX,DXPR,XEND
86.000       WRITE(IO,160)X,DX,DXPR,XEND
87.000 160   FORMAT('  X ='F4.2'    DX ='E10.3'     DXPR ='E10.3
85.000      1 '    XEND ='E10.3,/)
89.000       READ(IN,10) ERROR,DXMAX
90.000       WRITE(IO,180) ERROR,DXMAX
91.000 180   FORMAT('   ERROR ='E10.3'   DXMAX ='E10.3,/)
92.000       READ(IN,10)  DT,U,AREA,EL
93.000       READ(IN,10) RHO,WMPH,TAIR,CLD,RH,ALBAR
```

```
 94.000          DO 185 I=1,10
 95.000 185      READ(IN,10) PTBL(I), TTBL(I), HFGTB(I)
 96.000          TA = (TAIR - 32.)*5./9.
 97.000          W = WMPH*22./15.
 98.000          WMS = W * .3048
 99.000          WMD = WMPH * 24.
100.000          CONST = EL/(RHO*U*AREA)
101.000          CONS1 = (RHO*0.00328)/(24.*3600.*0.061)
102.000          READ(IN,10) DALP,DCLD,DRH,DTAIR,DWMPH
103.000          DTA = DTAIR*5./9.
104.000          HOS = 1.9*SIN(ALBAR*RATIO)
105.000          HOC = 1.9*COS(ALBAR*RATIO)
106.000          CLD1 = 1. - .0745*CLD
107.000          CLD2 = -.0018*CLD**2
108.000          CLD3 = 1. - .0006*CLD**3
109.000          DALPR = DALP * RATIO
110.000          DW = DWMPH*22./15.
111.000          DWMS = DW * .3048
112.000          DWMD = DWMPH*24.
113.000 C        INCIDENT SOLAR RADIATION
114.000          HS = HOS * CLD3
115.000 C        REFLECTED SOLAR RADIATION
116.000          HSR = HS * 3./ALBAR
117.000          FTA = SI(TTBL,PTBL,TAIR,10)
118.000          EA = RH*(1013./1470.)*FTA
119.000          TAIRP = TAIR+DTAIR
120.000          FTAP = SI(TTBL,PTBL,TAIRP,10)
121.000          DEA = (1013./1470.)*(DRH*FTA + RH*(FTAP - FTA))
122.000          WRITE(IO,200) DT
```

```
123.000 200   FORMAT('  INITIAL DT ='F12.4                '       DEG F'/)
124.000       WRITE(18,210) U,AREA,EL
125.000 210   FORMAT('  STREAM VELOCITY ='F6.3' FT/SEC   CR. SEC. AREA ='
126.000      1F10.2'  SQ. FT.     SURFACE WIDTH ='F6.1'  FT'/)
127.000       WRITE(18,220) RHO,CLD,RH,ALBAR
128.000 220   FORMAT('  RHO='F5.2'  LB/CU.FT.      CLD='F4.1'  TENTHS',
129.000      1'    RH='F5.1'  PCT'/'  ALBAR ='F4.1'  DEGREES'/)
130.000       WRITE(18,230) TAIR,TA,CONST,CONS1
131.000 230   FORMAT('  AIR TEMP. ='F5.1'  DEG F'F8.1'  DEG C',
132.000      1'    CONST ='E10.3'    CONS1 ='F10.3,/)
133.000       WRITE(18,240) W,WMPH,WMS,WMD
134.000 240   FORMAT('  WIND VELOCITY ='F6.2' FT/SEC'F8.2'MPH'F8.2' METERS',
135.000      1'/SEC'F8.2'  MILES/DAY'/)
136.000       WRITE(18,260)
137.000 260   FORMAT(/,T20'TTBL'T40'PTBL'T60'HFGTB'/)
138.000       DO 270 I =1,10
139.000 270   WRITE(18,280) TTBL(I), PTBL(I), HFGTB(I)
140.000 280   FORMAT(10X,3F20.5)
141.000       WRITE(18,300)DCLD,DRH,DTAIR
142.000 300   FORMAT(/'  DCLD ='F6.3'  DRH ='F5.3'  DTAIR ='F6.2)
143.000       WRITE(18,310) DALP,DWMPH
144.000 310   FORMAT(/'  DALP ='F6.2'  DWMPH ='F6.2)
145.000       WRITE(18,320) HOS,HOC,HS,HSR
146.000 320   FORMAT(/'  HOS='E12.4'  HOC='E12.4'  HS='E12.4'  HSR='E12.4' LY/MIN')
147.000      1N')
148.000       WRITE(18,330) EA,DEA
149.000 330   FORMAT(/'  EA ='E12.4'  DEA ='F12.4)
150.000       WRITE(19,340)
```

```
151.000 340   FORMAT(/,T20'STTBL'T40'XTBL'/)
152.000       READ(IN,20) NTEMP
153.000       DO 350 I =1,NTEMP
154.000       READ(IN,10)   STTBL(I),XTBL(I)
155.000       WRITE(IO,280) STTBL(I),XTBL(I)
156.000 350   CONTINUE
157.000       WRITE(IO,360)
158.000 360   FORMAT('1')
159.000       RETURN
160.000       END
161.000       SUBROUTINE OUPT
162.000       COMMON  DDT,       DT,XPR,XEND,DXPR,X,DX,INT,
163.000      1INTC, IN,IO,FL,AREA,U,ERROR,DXMAX,TEMP,HFGTB(10),CONS1
164.000       COMMON/RHO,WND,HD,TAIR,CLD,RH,ALBAR,TWS,TA,EW,EA,HOS,HS
165.000       COMMON HSR,HBB,EBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CONST
166.000       COMMON HFG,HBC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
167.000      1DTA,DN,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
168.000       WRITE(IO,10) X,DX
169.000  10   FORMAT('    X ='F7.1' FT    DX ='F6.1       ,/)
170.000       WRITE(IO,20) TEMP
171.000 20    FORMAT('  STREAM TEMP ='E12.4' DEG F'/)
172.000       WRITE(IO,70) DT,DDT
173.000       WRITE(IO,30) EW,DEW,EVAP,HE,HFG
174.000 30    FORMAT('  EW ='F12.5'   DEW ='F12.5'  EVAP ='E12.5'   HE ='
175.000      1E12.5'  LY/MIN    HFG ='E12.5,/)
176.000       WRITE(IO,50) HSR,EBR,HC
177.000 50    FORMAT('  HSR ='E12.5'   EBR='F12.5'   HC  ='E12.5'  LY/MIN'/)
178.000       WRITE(IO,60) HLYMN,HD
179.000 60    FORMAT('  TOTAL HEAT TRANSFER ='E12.5'  LY/MIN'E15.5,
```

```
180.000      1'   BTU/SEC-FT2'/)
181.000 70    FORMAT(' DT ='E12.5'    DDT ='E12.5,/)
182.000       WRITE(19,80) DLYMN,DBTUS
183.000 80    FORMAT(' DLYMN ='E12.5'    DBTUS ='E12.5,/)
184.000       WRITE(19,90)
185.000 90    FORMAT(1X,60('*'),//)
186.000       RETURN
187.000       END
188.000       SUBROUTINE DIFEQ
189.000       COMMON  DDT,DT,           XPR,XEND,DXPR,X,DX,
190.000      1INT,INTC, IN,IO,EL,AREA,U,ERROR,DXMAX,TEMP,HFGTB(10),CONS1
191.000       COMMON HSR,HBB,EBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CONST
192.000       COMMON HFG,HBC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
193.000      1DTA,DW,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
194.000 C     THERMAL EXCHANGE WITH ENVIRONMENT.
195.000       TEMP = SI(XTBL,STTBL,X,NTEMP)
196.000       TWS= (TEMP-32.)*5./9.
197.000       DTWS = DT*5./9.
198.000       FTA = SI(TTBL,PTBL,TEMP,10)
199.000       TTW = TEMP + DT
200.000       FTB = SI(TTBL,PTBL,TTW,10)
201.000       EW = (1013./14.7)*FTA
202.000       DEW = (1013./14.7)*(FTB - FTA)
203.000 C     EFFECTIVE BACK RADIATION.
204.000       HBB= (14.38-.09*TWS-.046*RH)/69.72
205.000       EBR = HBR*CLD1
206.000 C     EVAPORATION HEAT TRANSFER.
```

```
208.000        EVAP = .35* (EW-EA)*(1. + .0098* WMD)
209.000        HFG = SI(TTBI,HFGTR,TEMP,10)
210.000        HE = EVAP*HFG*CONS1
211.000 C      CONVECTION HEAT TRANSFER
212.000        HC = 39.*(.26 + .077*WMS)*(TWS - TA )/1440.
213.000 C      TOTAL HEAT TRANSFER TO WATER, LY/MIN
214.000        HLYMN = HS - (EBR + HSR + HC + HE)
215.000 C      TOTAL HEAT TRANSFER, BTU/SEC-FT2
216.000        HD = HLYMN * .0614
217.000        F1 = CLD2*DCLD*H8S
218.000        F2 = CLD3*H8C*DALPR
219.000        F3 = .0765*DCLD*H8B
220.000        F4 = -CLD1*(-.09*DTWS - .046*DRH)/69.72
221.000        F5 = -(F1+F2)*3./ALBAR
222.000        F6 = HS*3.*DALP/ALBAR**2
223.000        F7 = -(.35*HFG/14400.)*((1. + .0098*WMD)*(DEW - DEA) +
224.000       1 .0098*DWMD*(EW - EA))
225.000        F8 = -(39./1440.)*((.26 + .077*WMS)*(DTWS - DTA) +
226.000       1 .077*DWMS*(TWS - TA))
227.000        DLYMN = F1 + F2 + F3 + F4 + F5 + F6 + F7 + F8
228.000        DBTUS = DLYMN*.0614
229.000        DDT = CONST*DBTUS
230.000        RETURN
231.000        END
232.000 CCCCC
233.000 CCCCC
234.000 CCCCC
235.000 CCCCC
```

```
236.000       FUNCTION SI(XTBL,YTBL,X,N)
237.000 C     LINEAR INTERPOLATION OR EXTRAPOLATION OF SINGLE VARIABLE FUNCTION
238.000 C     XTBL = INDEPENDENT VARIABLE TABLE
239.000 C     YTBL = DEPENDENT VARIABLE TABLE
240.000 C     IND = INDICATOR OF EXTRAPOLATION
241.000 C     0=NO EXTRAPOLATION, 1=LOWER EXTRAPOLATION, 2=UPPER EXTRAPOLATION
242.000       DIMENSION XTBL(40),YTBL(40)
243.000 C     CHECK TO SEE IF EXTRAPOLATION IS NEEDED.
244.000       IF(X-XTBL(1)) 120,130,150
245.000   120 IND = 1
246.000   130 II = 2
247.000       GO TO 254
248.000   150 IF(XTBL(N)-X) 160,180,210
249.000   160   IND = 2
250.000   180   II = N
251.000       GO TO 254
252.000 C     FIND X IN TABLE.S IN TABLE
253.000   210 DO 220 IK=2,N
254.000       II = IK
255.000       IF(XTBL(IK)-X) 220,254,254
256.000   220 CONTINUE
257.000   254 X1 = XTBL(II-1)
258.000       X2 = XTBL(II)
259.000       Y1 = YTBL(II-1)
260.000       Y2 = YTBL(II)
261.000       SI = Y1+(Y2-Y1)*(X-X1)/(X2-X1)
262.000       RETURN
263.000       END
264.000 CCCCC
```

```
C     EULER AND MODIFIED EULER INTEGRATION

      SUBROUTINE EULER(YP,Y,DT,NE,J,T)
      DIMENSION YP(20),Y(20), SY(20),SYP(20)
      GO TO(10,20),J
   10 CONTINUE
      DO 100 I=1,NF
      SY(I)= Y(I)
      SYP(I)= YP(I)
      Y(I)= Y(I)+DT*YP(I)
  100 CONTINUE
      T=T+DT
      RETURN
   20 CONTINUE
      DO 200 I=1,NF
      Y(I)= SY(I)+(YP(I)+SYP(I))*DT/2.
  200 CONTINUE
      RETURN
      END

C     FOURTH ORDER RUNGE-KUTTA INTEGRATION
```

```
294.000          SUBROUTINE RK4(YP,Y,DT,NE,J,T)
295.000          DIMENSION YP(5),Y(5),AK(5,4),SY(5)
296.000          GO TO(10,20,30,40),J
297.000 10       CONTINUE
298.000          DO 100 I=1,NE
299.000          SY(I) = Y(I)
300.000          AK(I,1) = DT*YP(I)
301.000          Y(I) = Y(I) +AK(I,1)*.5
302.000 100      CONTINUE
303.000          ST = T
304.000          T = T + DT*.5
305.000          RETURN
306.000 20       CONTINUE
307.000          DO 200 I=1,NE
308.000          AK(I,2) = DT*YP(I)
309.000          Y(I) = SY(I) + AK(I,2)*.5
310.000 200      CONTINUE
311.000          RETURN
312.000 30       CONTINUE
313.000          DO 300 I = 1,NE
314.000          AK(I,3) = DT*YP(I)
315.000          Y(I) = SY (I) + AK(I,3)
316.000 300      CONTINUE
317.000          T = ST + DT
318.000          RETURN
319.000 40       CONTINUE
320.000          DO 400 I = 1,NE
321.000          AK(I,4) = DT *YP(I)
```

```
      Y(I)=SY(I)+(AK(I,1)+AK(I,4)+2.*(AK(I,2)+AK(I,3)))/6.
400   CONTINUE
      RETURN
      END
CCCCC
CCCCC
CCCCC
C     ADAMS-MOULTON INTEGRATION
CCCCC
CCCCC
CCCCC
      SUBROUTINE NEWRD(F,T,TLIM,Y,ERROR,NE,H,HMAX,JUMP,KSTP,KCON,CLIF,IE)
      DIMENSION STARY(5),Y(5),SY(5),SAVEY(5),F(5),FP(5),DELTA(5),DALTA(5
     1),A(5),B(5),C(5),D(5),AA(5),BB(5),CC(5),DD(5),SF(5)
      IF(KSTP-32767)993,991,991
  991 KSTP=28
C     TEST FOR TYPE OF ENTRY
  993 IF(JUMP)1,998,999
  998 GO TO (1000,11,21,802,803),IA
C     JUMP POS.    RESTORE VALUES
  999 T=SAVET
  992 JUMP=0
      DO 901 I=1,NE
      F(I)=SF(I)
  901 Y(I)=SAVEY(I)
      GO TO 102
C     JUMP NEG.      INITIALIZE
    1 DO 5 I=1,NE
      STARY(I)=Y(I)
```

```
351.000          A(I)=0.001
352.000          B(I)=0.001
353.000          C(I)=0.001
354.000        5 D(I)=0.001
355.000          KSTP=0
356.000          KDELY=0
357.000          KCBN=0
358.000          XT=95./(288.*64.)
359.000          U=863./(12.*5040.)
360.000          V=95.0/288.0
361.000          P=25.0/24.0
362.000          Q=35.0/72.0
363.000          R=5.0/48.0
364.000          S=1.0/120.0
365.000          IA=1
366.000          JJMP=0
367.000          GO TO 1101
368.000 C        BEGIN INTEGRATION STEP
369.000  1000    DO 1111 I=1,NE
370.000          SF(I)=F(I)
371.000  1111    SAVEY(I)=Y(I)
372.000 C        H TOO SMALL  RETURN WITH JUMP NEG.
373.000   600    IF(ABS(T+H)-ABS(T))605,601,605
374.000   601    JJMP=-1
375.000          GO TO 1101
376.000   605    T=T+H
377.000          DO 10 I=1,NE
378.000          Y(I)=Y(I)+H*(F(I)+A(I)+B(I)+C(I)+D(I))
```

```
379.000     10 FP(I)=F(I)+2.0*A(I)+3.0*B(I)+4.0*C(I)+5.0*D(I)
380.000        IA=2
381.000        GO TO 1101
382.000     11 DO 12 I=1,NE
383.000     12 SY(I)=Y(I)
384.000        DO 20 I=1,NE
385.000        DELTA  (I)=F(I)-FP(I)
386.000     20 Y(I)=Y(I)+V*DELTA  (I)*H
387.000        IA=3
388.000        KCONV=1
389.000        GO TO 1101
390.000     21 KCONV=0
391.000        DO 30 I=1,NE
392.000        DALTA  (I)=F(I)-FP(I)
393.000     29 Y(I)=SY(I)+V*DALTA  (I)*H
394.000     30 CONTINUE
395.000 C      TEST FOR STARTING SEQUENCE
396.000     31 IF(KSTP-28)35,40,40
397.000 C      APPLY TEST 2 ON ZEROTH STEP
398.000     35 IF(KSTP)50,50,60
399.000 C      HALVING TESTS
400.000     40 DO 45 I=1,NE
401.000        IF(ABS(DALTA  (I))-ERROR/ABS(H))45,45,55
402.000     45 CONTINUE
403.000     50 IF(V*H*CLIF-0.125)60,60,55
404.000     55 T=T-H
405.000 C      FAIL TESTS, HALVE H
406.000   223 H=H/2.0
407.000        KDELY=0
```

```
408.000        DO 56 I=1,NE
409.000        A(I)=A(I)/2.0
410.000        B(I)=B(I)/4.0
411.000        C(I)=C(I)/8.0
412.000        F(I)=SF(I)
413.000        Y(I)=SAVEY(I)
414.000     56 D(I)=D(I)/16.0
415.000        GO TO 1000
416.000 C      PASS TESTS, CORRECT A,B,C,D
417.000     60 KSTP=KSTP+1
418.000        DO 65 I=1,NE
419.000        A(I)=A(I)+3.0*B(I)+6.0*C(I)+10.0*D(I)+P*DALTA  (I)
420.000     62 B(I)=B(I)+4.0*C(I)+10.0*D(I)+Q*DALTA(I)
421.000     64 C(I)=C(I)+5.0*D(I)+R*DALTA(I)
422.000     67 D(I)=D(I)+S*DALTA(I)
423.000     65 CONTINUE
424.000 C      IF IN STARTING SEQUENCE, BRANCH
425.000        IF(KSTP-24)70,90,100
426.000     70 GO TO (1000,1000,1000,74,1000,1000,1000,78,1000,1000,1000,74,1000,
427.000       11000,1000,86,1000,1000,1000,74,1000,1000,1000),KSTP
428.000 C      4TH, 12TH, 20TH STEP, GO BACK
429.000     74 H=-H
430.000        DO 75 I=1,NE
431.000        A(I)=-A(I)
432.000     75 C(I)=-C(I)
433.000        GO TO 1000
434.000 C      8TH STEP  GO FORWARD
435.000     78 H=-H
```

```
436.000         DO 79 I=1,NE
437.000         Y(I)=STARY(I)
438.000         A(I)=-A(I)
439.000      79 C(I)=-C(I)
440.000         GO TO 1000
441.000 C       16TH STEP, HALVE H, APPLY TEST 1
442.000      86 H=H/2.0
443.000         DO 87 I=1,NE
444.000         A(I)=A(I)/2.0
445.000         B(I)=B(I)/4.0
446.000         C(I)=C(I)/8.0
447.000      87 D(I)=D(I)/16.0
448.000         DO 88 I=1,NE
449.000         IF(ABS(DALTA  (I))-ERROR/ABS(H))88,88,89
450.000      88 CONTINUE
451.000 C       PASS TEST   GO FORWARD WITH HALVED H
452.000         GO TO 78
453.000 C       FAIL TEST   BEGIN AGAIN WITH HALVED H
454.000      89 H=-H
455.000         DO 92 I=1,NE
456.000      92 Y(I)=STARY(I)
457.000         GO TO 1
458.000 C       24TH STEP, DOUBLE H, STARTING SEQUENCE ENDS
459.000      90 H=H+2.0
460.000         DO 91 I=1,NE
461.000         A(I)=A(I)+2.0
462.000         B(I)=B(I)+4.0
463.000         C(I)=C(I)+8.0
464.000      91 D(I)=D(I)+16.0
```

```
      GO TO 78
  100 KOELY=KOELY+1
C     WILL NEXT STEP MOVE PAST TLIM
  102 IF(ABS(TLIM-T)-ABS(H))103,103,110
C     YES.........SAVE T AND Y, INTEGRATE TO TLIM,RETURN.
  103 ENDH=TLIM-T
      DO 105 I=1,NE
      AA(I)=ENDH*A(I)/H
      BB(I)=ENDH**2*B(I)/H**2
      CC(I)=ENDH**3*C(I)/H**3
  105 DD(I)=ENDH**4*D(I)/H**4
      SAVET=T
      DO 800 I=1,NE
      SF(I)=F(I)
  800 SAVEY(I)=Y(I)
  806 T=TLIM
      DO 106 I=1,NE
      Y(I)=Y(I)+ENDH*(F(I)+AA(I)+BB(I)+CC(I)+DD(I))
  106 FP(I)=F(I)+2.0*AA(I)+3.0*BB(I)+4.0*CC(I)+5.0*DD(I)
      IA=4
      GO TO 1101
  802 DO 805 I=1,NE
  805 SY(I)=Y(I)
      DO 107 I=1,NE
      DELTA  (I)=F(I)-FP(I)
  107 Y(I)=Y(I)+V*DELTA  (I)*ENDH
      IA=5
      GO TO 1101
```

```
493.000    803 DO 108 I=1,NF
494.000        DALTA  (I)=F(I)-FP(I)
495.000    108 Y(I)=SY(I)+V*DALTA  (I)*ENDH
496.000        JUMP=1
497.000        GO TO 1101
498.000 C      NO.....TEST FOR DOUBLING. IF OK, BEGIN NEXT STEP AFTER DOUBLING
499.000    110 IF(ABS(TIM-T)-ABS(2.0*H))1000,1000,111
500.000    111 IF(KDELY-4)1000,120,120
501.000    120 IF(ABS(2.0*H)-ABS(HMAX))121,121,1000
502.000    121 DO 125 I=1,NF
503.000        IF(ABS(DALTA  (I))-ERROR/(128.0*ABS(H)))125,125,1000
504.000    125 CONTINUE
505.000        IF(V*H*CI IF-0.0425)130,1000,1000
506.000    130 CONTINUE
507.000    335 H=2.0*H
508.000        DO 135 I=1,NF
509.000        A(I)=2.0*A(I)
510.000        B(I)=4.0*B(I)
511.000        C(I)=8.0*C(I)
512.000    135 D(I)=16.0*D(I)
513.000        KDELY=0
514.000        GO TO 1000
515.000   1101 CONTINUE
516.000   1150 FORMAT(/,2X,'HH =',2X,F10.6,14X,'KSTP =',2X,I3,10X,'DAL3A(I)',/)
517.000   1151 FORMAT(5(2X,I2,1X,E14.7))
518.000        RETURN
519.000        END
```

```
C     C(1000)=CLOUD COVER
C     TA(1000)=AIR TEMP.
C          PHI(1000)= REL HUMIDITY
C          W(1000)= WIND SPEED
C          TW(1000)= WATER TEMP
C          NCAS= NO. OF CASES
C          NDA= NO. OF DAYS TO BE TRIED
C          DELT(50)= ERROR CRITERION TO BE SATISFIED
C          IDAS(50)= NO. OF DAYS IN TRIAL
C          NLN= NO. OF LINES
C          DT= ERROR CRITERION FOR THE SPECIFIC CASE
C          NTA= NO. OF TIME AVERAGED DATA POINTS
C          UA,EL,CC,.....,WSP= ACTUAL DATA AT VERNON
C          INT2,INT3= DATA POINT NUMBERS
C          DC,DTA,.....,DT_A= ERROR IN VARIABLES
           COMMON YP1(5),Y1(5),XPR1,XEND1,DXPR1,X1,DX1,NE1,INT1,INTC1,IN1,I81
          1,EL1,AREA1,U1
           COMMON ERROR1,DXMAX1,TEMP1,HEGTB1(10),CONST1
           COMMON RHO1,W1,WMD1,HD1,TAIR1,CLD1,RH1,ALBAR1,TWS1,TA1,TWSA1,EW1,
          1EA1,H0S1,HS1
           COMMON HSR1,H0B1,FBR1,EVAP1,HE1,HC1,HLYMN1,PTBL1(10),TTBL1(10),
          1WMS1,CONST1
           COMMON CLIF1,HEG1,H0C1,CLD11,CLD21,CLD31,DALP1,DALPR1,DCLD1,DRH1,
          1DTAIR1,DTA1,DW1,DWMS1,DWMD1,DEA1,DEW1,DLYMN1,DBTUS1,NTEMP1,
          2STTBL1(10),XTBL1(10)
           COMMON C(1000),TA(1000),PHI(1000),W(1000),TW(1000)
           COMMON NCAS, NDA, DELT(50), IDAS(50)
           COMMON NLN,IN,I80,DT,NTA,IDA
           COMMON CTA(50),TATA(50),PHITA(50),WTA(50),TWTA(50)
```

```
      COMMON UA,EL,CC,TAIR,TWA,RH,WSP
      COMMON INT2,INT3,DC,DTA,DPHI,DW,DTW,INVS,IFLAG
      COMMON DM21,BETA
      COMMON LAG1,NDAS
      COMMON ICAS,PRP(50,10)
CCCCC
CCCCC
CCCCC
CCCCC
      CALL RREAD
      DT=1.
      DO 20 IDA=1,NDAS
      CALL PRBR
   20 CONTINUE
      CALL PRBU
      CALL VERSON
      CALL EXIT
      END
C     SUBROUTINE FOR READING IN DATA
CCCCC
CCCCC
CCCCC
CCCCC
CCCCC
      SUBROUTINE RREAD
      COMMON YP1(5),Y1(5),XPR1,XEND1,DXPR1,X1,DX1,NE1,INT1,INTC1,IN1,IB1
     1,EL1,AREA1,U1
```

```
57.000        COMMON ERRBR1,DXMAX1,TEMP1,HFGTR1(10),CONS11
58.000        COMMON RHO1,W1,WMD1,HD1,TAIR1,CLD1,RH1,ALBAR1,TWS1,TA1,TWSA1,EW1,
59.000       1EA1,HBS1,HS1
60.000        COMMON HSR1,HBB1,EBR1,EVAP1,HE1,HC1,HLYMN1,PTBL1(10),TTBL1(10),
61.000       1WMS1,CONST1
62.000        COMMON CLIF1,HFG1,HBC1,CLD11,CLD21,CLD31,DALP1,DALPR1,DCLD1,DRH1,
63.000       1DTAIR1,DTA1,DW1,DXMS1,DWMD1,DEA1,DEW1,DLYMN1,DBTUS1,NTEMP1,
64.000       2STTBL1(10),XTBL1(10)
65.000        COMMON C(1000),TA(1000),PHI(1000),W(1000),TW(1000)
66.000        COMMON NDAS, NDA, DELT(50), IDAS(50)
67.000        COMMON NLN,IN,IBU,DT,NTA,IDA
68.000        COMMON CTA(50),TATA(50),PHITA(50),WTA(50),TWTA(50)
69.000        COMMON UA,EL,CC,TAIR,TWA,RH,WSP
70.000        COMMON INT2,INT3,DC,DTA,DPHI,DW,DTW,INVS,IFLAG
71.000        COMMON DM21,BETA
72.000        COMMON LBG1,NDAS
73.000        COMMON ICAS,PRP(50,10)
74.000        IN=101
75.000        IBU=102
76.000  1000  FORMAT(6F10.3)
77.000  1001  FORMAT(6I10)
78.000        READ (IN,1001) NLN,LBG1
79.000        WRITE(IBU,2000)NLN,LBG1
80.000  2000  FORMAT(1HO,2X,'NUMBER OF DATA LINES=',I5,'TIME AV. LOGIC=',I5)
81.000        WRITE(IBU,2001)
82.000  2001  FORMAT(1HO,2X,'CLD COVER  AIRTEMP  REL HUM  WIND SPD  WATER TEMP')
83.000        DO 10 I= 1,NLN
84.000        READ(IN,1000) C(I),TA(I),PHI(I),W(I),TW(I)
85.000        WRITE(IBU,2002)C(I),TA(I),PHI(I),W(I),TW(I)
```

```
 2002 FORMAT(1HO,2X,5(F10.3,1X))
   10 CONTINUE
C     PLANT DATA
C     UA=VEL, EL=RIVER WIDTH, CL=CLOUD COVER, TAIR=OBVIOUS
C     TWA=WATER TEMP, RH=REL HUMIDITY, WSP=WIND SPEED(KNOTS)
      READ(IN,1000)UA,EL,CC,TAIR
      WRITE (IOU,2003)UA,EL,CC,TAIR
 2003 FORMAT(1HO,2X,'UA=',1X,F10.3,'R  WIDTH=',1X,F10.3,'CLD  COVER=',
     11X,F10.3,'TEMP  AIR=',1X,F10.3)
      READ(IN,1000)TWA,RH,WSP
      WRITE(IOU,2004)TWA,RH,WSP
 2004 FORMAT('O',2X,'TEMP WATER=',1X,F10.3,'REL  HUM=',1X,F10.3,'WIND
     1SPEED=',1X,F10.3)
      IF(L831)15,16,15
   15 CONTINUE
      READ(IN,1001)NTA
      WRITE(IOU,2005)NTA
 2005 FORMAT(1HO,2X,'NUMBER OF TIME AV. DATA POINTS=',1X,I5)
      WRITE(IOU,2006)
 2006 FORMAT('O',2X,'CLD COVER TA   AIR TEMP TA   REL HUM TA   WIND TA
     1   TEMP WATER TA')
      DO 20 I=1,NTA
      READ(IN,1000) CTA(I),TATA(I),PHITA(I),WTA(I),TWTA(I)
      WRITE(IOU,2007)CTA(I),TATA(I),PHITA(I),WTA(I),TWTA(I)
 2007 FORMAT(1HO,2X,5(F10.3,1X))
   20 CONTINUE
   16 CONTINUE
      READ(IN,1001)NCAS
```

```
      WRITE(IOU,2008)NCAS
2008 FORMAT(1HO,2X,'NUMBER OF CASES=',1X,I4)
      READ(IN,3000)(DELT(I), I=1,NCAS)
3000 FORMAT(6F10.3)
      WRITE(IOU,3010)
3010 FORMAT(1HO,2X,'ALLOWED DTS')
      WRITE(IOU,2009)(DELT(I),I=1,NCAS)
2009 FORMAT(1HO,2X,E14.7)
      READ(IN,1001)NDAS
      WRITE(IOU,2010)NDAS
2010 FORMAT('0',2X,'NUMBER OF DAYS AVERAGED=',2X,I4)
      READ(IN,1001)(IDAS(I), I=1,NDAS)
      WRITE(IOU,3011)
3011 FORMAT(1HO,2X,'DAYS AVERAGED')
      WRITE(IOU,2050)(IDAS(I),I=1,NDAS)
2050 FORMAT(1HO,2X,I5)
      WRITE(IOU,2011)
2011 FORMAT(1HO,2X,'PTBL1     TTBL1     HFGTB1',//,2X,60('*'))
      DO 185 I=1,10
      READ(IN,1002) PTBL1(I),TTBL1(I),HFGTB1(I)
      WRITE(IOU,2012)PTBL1(I),TTBL1(I),HFGTB1(I)
2012 FORMAT(6F10.3)
1002 FORMAT(6F10.3)
 185 CONTINUE
      READ(IN,1000) DM21,BETA
      WRITE(IOU,2013)DM21,BETA
      BETA=BETA/57.296
2013 FORMAT(1HO,2X,'DAYS SINCE MARCH 21=',2X,F10.3,'BETA=',2X,F10.3)
      DO 30 IDA=1,NDAS
```

```
      DO 40 ICAS=1,NCAS
      PRP(IDA,ICAS)=0.
   40 CONTINUE
   30 CONTINUE
      RETURN
      END
CCCCC
CCCCC
CCCCC
CCCCC
CCCCC
      SUBROUTINE PROB
      COMMON YP1(5),Y1(5),XPR1,XEND1,DXPR1,X1,DX1,NE1,INT1,INTC1,IN1,IO1
     1,EL1,AREA1,U1
      COMMON ERPOR1,DXMAX1,TEMP1,HEGTR1(10),CONST1
      COMMON RHO1,W1,WMO1,HO1,TAIR1,CLD1,RH1,ALBAR1,TWS1,TA1,TWSA1,EW1,
     1EA1,HOS1,HS1
      COMMON HSR1,HOB1,EBR1,EVAP1,HE1,HC1,HLYMN1,PTBL1(10),TTBL1(10),
     1W1S1,CONST1
      COMMON CLIF1,HEG1,HBC1,CLD11,CLD21,CLD31,DALP1,DALPR1,DCLD1,DRH1,
     1DTAIR1,DTA1,DW1,DWMS1,DWMO1,DEA1,DEW1,DLYMN1,DBTUS1,NTEMP1,
     2STTBL1(10),XTBL1(10)
      COMMON C(1000),TA(1000),PHI(1000),W(1000),TW(1000)
      COMMON NCAS, NDA, DELT(50), IDAS(50)
      COMMON NIN,IN,IOU,DT,NTA,IDA
      COMMON CTA(50),TATA(50),PHITA(50),WTA(50),TWTA(50)
      COMMON UA,EL,CC,TAIR,TWA,RH,WSP
      COMMON INT2,INT3,DC,DTA,DPHI,DW,DTW,INVS,IFLAG
```

```
171.000         COMMON DM21,BETA
172.000         COMMON LAG1,NDAS
173.000         COMMON IDAS,PRP(50,10)
174.000         DIMENSION PR(10)
175.000 C       NDA= NUMBER OF DAYS IN THE CASE
176.000         ID=IDA
177.000         NDA=IDAS(ID)
178.000         NC1=NLN/8
179.000         FNDA=NDA-8
180.000         FNDA=1/FNDA
181.000         IF(NDA-NC1) 10,999,999
182.000      10 CONTINUE
183.000         NDIF=NC1-NDA
184.000         ENUM=0.
185.000         DEN=0.
186.000         DENP=0.
187.000         DO 20 IP0=1,NDIF
188.000         CS=0.
189.000         TAS=0.
190.000         PHIS=0.
191.000         WS=0.
192.000         TWS=0.
193.000         DO 30 I=1,NDA
194.000         DO 40 J=1,8
195.000         INT=8*(IP0+I-1)+J-8
196.000         CS=CS + C(INT)
197.000         TAS=TAS + TA(INT)
198.000         PHIS=PHIS + PHI(INT)
```

```
199.000          WS=WS + W(INT)
200.000          TWS= TWS + TW(INT)
201.000       40 CONTINUE
202.000       30 CONTINUE
203.000          CS= CS*ENDA
204.000          TAS= TAS*ENDA
205.000          PHIS=PHIS*ENDA
206.000          WS= WS*ENDA
207.000          TWS= TWS*ENDA
208.000 C        INTP= PRECEDING DAY
209.000          INTP= 120*NDA
210.000          C1S=0.
211.000          TA1S=0.
212.000          PHI1S=0.
213.000          W1S=0.
214.000          TW1S=0.
215.000          DO 50 I=1,8
216.000 C        INTR= THE ACTUAL POSITION IN THE DAY
217.000          INTR=INTP*8-R+I
218.000          C1S=C1S+C(INTR)
219.000          TA1S=TA1S+TA(INTR)
220.000          PHI1S=PHI1S+PHI(INTR)
221.000          W1S=W1S+W(INTR)
222.000          TW1S=TW1S+TW(INTR)
223.000       50 CONTINUE
224.000          C1S=C1S*.125
225.000          TA1S=TA1S*.125
226.000          PHI1S=PHI1S*.125
227.000          W1S=W1S*.125
```

```
228.000         TW1S=TW1S+.125
229.000         DC=C1S-CS
230.000         DTA=TA1S-TAS
231.000         DPHI=PHI1S-PHIS
232.000         DW=W1S-WS
233.000         DTW=TW1S-TWS
234.000         STTBL1(1)=TW1S
235.000         STTBL1(2)=TW1S
236.000         XTBL1(1)=0.
237.000         XTBL1(2)=25000.
238.000         NTBP1=2
239.000         INVS=INT2*8-4
240.000         CALL COMP(ENUM,DEN)
241.000         DO 80 ICAS=1,NCAS
242.000         IF(ABS(Y1(1))-DELT(ICAS)) 65,65,70
243.000    65   CONTINUE
244.000         PRP(IDA,ICAS)=PRP(IDA,ICAS)+1.
245.000    70   CONTINUE
246.000    80   CONTINUE
247.000    90   CONTINUE
248.000         DENP=NDIF
249.000         DO 75 ICAS=1,NCAS
250.000         PRP(IDA,ICAS)=PRP(IDA,ICAS)/DENP
251.000    75   CONTINUE
252.000         IF(LOB1)200,201,200
253.000   200   CONTINUE
254.000         ENUM=0.
255.000         DEN=0.
256.000         DENP=0.
```

```
257.000          C(1000)=CC
258.000          TA(1000)=TAIR
259.000          PHI(1000)=RH
260.000          W(1000)=WSP
261.000          TW(1000)=TWA
262.000          DO 205 ICAS=1,NCAS
263.000          PR(ICAS)=0.
264.000      205 CONTINUE
265.000          DO 210 I=1,NTA
266.000          DC=CTA(I)-CC
267.000          DTA=TATA(I)-TAIR
268.000          DPHI=PHITA(I)-RH
269.000          DW=WTA(I)-WSP
270.000          DTW=TWTA(I)-TWA
271.000          STTBL1(1)=TA(1000)
272.000          STTBL1(2)=TA(1000)
273.000          XTBL1(1)=0.
274.000          XTBL1(2)=25000.
275.000          NTEMP1=2.
276.000          INVS=1000
277.000          CALL COMP(ENUM,DEN)
278.000          DO 80 ICAS=1,NCAS
279.000          IF(ABS(Y1(1))-DELT(ICAS))85,85,80
280.000       85 CONTINUE
281.000          PR(ICAS)=PR(ICAS)+1.
282.000       80 CONTINUE
283.000      210 CONTINUE
284.000          FNTA=NTA
```

```
      DO 90 ICAS=1,NCAS
      PR(ICAS)=PR(ICAS)/ENTA
      CALL BUTT(I8U,PR(ICAS),IDA)
   90 CONTINUE
  901 CONTINUE
      RETURN
  999 CONTINUE
      WRITE(I9U,4000)
 4000 FORMAT(1H9,2X,'TOO SMALL')
      CALL EXIT
      END
CCCCC
CCCCC
CCCCC
CCCCC
CCCCC
      SUBROUTINE BUTT(I3U,P,I)
      WRITE(I9U,2000)I,P
 2000 FORMAT(1H9,2X,'CASE',I4,2X,'PROBABILITY',E14.7)
      RETURN
      END
CCCCC
CCCCC
CCCCC
CCCCC
      SUBROUTINE  COMP(ENUM,DEN)
      COMMON YP1(5),Y1(5),XPR1,XEND1,DXPR1,X1,DX1,NE1,INT1,INTC1,IN1,I01
     1,EL1,AREA1,U1
      COMMON ERROR1,DXMAX1,TEMP1,HFGT81(10),CONS11
```

```
388.000         COMMON RH01,W1,WMO1,HO1,TAIR1,CLD1,RH1,ALBAR1,TWS1,TA1,TWSA1,EW1,
389.000        1EA1,HOS1,HS1
390.000         COMMON HSR1,HOB1,EBR1,EVAP1,HE1,HC1,HLYMN1,PTBL1(10),TTBL1(10),
391.000        1WMS1,CONST1
392.000         COMMON CLIF1,HEG1,H0C1,CLD11,CLDP1,CLD31,DALP1,DALPR1,DCLD1,DRH1,
393.000        1DTAIR1,DTA1,DW1,DWMS1,DWMO1,DEA1,DEW1,DLYMN1,DBTUS1,NTEMP1,
394.000        2STTBL1(10),XTBL1(10)
395.000         COMMON C(1000),TA(1000),PHI(1000),W(1000),TW(1000)
396.000         COMMON NCAS, NDA, DELT(50), IDAS(50)
397.000         COMMON NIN,IN,IOU,DT,NTA,IDA
398.000         COMMON CTA(50),TATA(50),PHITA(50),WTA(50),TWTA(50)
399.000         COMMON UA,EL,CC,TAIR,TWA,RH,WSP
400.000         COMMON INT2,INT3,DC,DTA,DPHI,DW,DTW,INVS,IFLAG
401.000         COMMON DM21,BETA
402.000         COMMON LAG1,NDAS
403.000         COMMON ICAS,PRP(50,10)
404.000         RH01=60.4
405.000         X1=0.
406.000         Y1(1)=DTW
407.000         XEND1=25000.
408.000         DXPR1=XEND1
409.000         DX1=1000.
410.000         NE1=1
411.000         IN1=IN
412.000         IO1=IOU
413.000         EL1=EL
414.000         AREA1=UA
415.000         U1=1.
```

```
416.000         ERR0R1=.01
417.000         DXMAX1=25000.
418.000         TEMP1=TW(INVS)
419.000         W1=V(INVS)*6080./3600.
420.000         WMS1=W1*.3048
421.000         WMD1=W1*3600.*24./5280.
422.000         WMPH1=WMD1/24.
423.000         TAIR1=TA(INVS)
424.000         CLD1=C(INVS)
425.000         RH1=PHI(INVS)
426.000         ALBAR1=ALBNAF(DMP1,BETA)
427.000         ALBAR1=ALBAR1*57.296
428.000         TWS1=5.*(TEMP1-32.)/9.
429.000         TA1=5.*(TAIR1-32.)/9.
430.000         DALP1=5.
431.000         DALPR1=DALP1/57.296
432.000         DCLD1=DC
433.000         DRH1=DPHI
434.000         DTAIR1=DTA
435.000         DW1=DW*6080./3600.
436.000         DWMS1=DW1*.3048
437.000         DWMD1=DW1*3600.*24./5280.
438.000 CCCCC
439.000 CCCCC
440.000 CCCCC
441.000 CCCCC
442.000         CALL HUNDL
443.000 CCCCC
444.000 CCCCC
```

```
      CCCCC
            IFLAG=0
            IF(ABS(Y1(1))-DT)10,10,20
         10 CONTINUE
            ENUM=ENUM+1.
            IFLAG=1
         20 CONTINUE
            DEN=DEN+1.
            RETURN
            END
      CCCCC
      CCCCC
      CCCCC
      CCCCC
            FUNCTION ALNAP(DMP1,BETA)
            SN1=SIN(BETA)
            TH1= 6.28*DMP1/ 365.
            DEL= ASIN(SIN((23.45/57.296))*SIN(TH1))
            PHY=ACOS(TAN(DEL)*TAN(BETA))
            T0=24.*PHY/6.28
            T1=24.-T0
            AV=(T1-T0)*SIN(DEL)*SN1/24.
            AV=AV-COS(DEL)*COS(BETA)*(SIN(6.28*T1/24.)-SIN(6.28*T0/24.))/6.28
            ALNAP=ASIN(AV)
            RETURN
            END
      CCCCC
      CCCCC
```

```
473.000 CCCCC
474.000 CCCCC
475.000 CCCCC
476.000       SUBROUTINE HUNDL
477.000 C     STREAM THERMAL MODEL      ****   SENSITIVITY ANALYSIS   ****
478.000       COMMON YP(5),Y(5),XPR,XEND,DXPR,X,DX,NE,INT,INTC,IN,IO,EL,AREA,U
479.000       COMMON ERROR,DXMAX,TEMP,HFGTB(10),CONST
480.000       COMMON WRHO,W,WMO,HO,TAIR,CLD,RH,ALBAR,TWS,TA,TWSA,EW,EA,HOS,HS
481.000       COMMON HSR,HAO,FBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CONST
482.000       COMMON CLIF,HFG,HBC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
483.000      1DTA,DW,DWMS,DWMO,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
484.000       CLIF = 1.E-6
485.000       CALL INPUT
486.000       IF(INTC - 4) 4,105,105
487.000 4     XPR = DXPR
488.000 5     CONTINUE
489.000       DO 100 JE= 1,INT
490.000       CALL DIFFQ
491.000       GO TO (10,10,20), INTC
492.000 10    CALL EULER(YP,Y,DX,NE,JE,X)
493.000       GO TO 100
494.000 20    CALL RK4(YP,Y,DX,NE,JE,X)
495.000 100   CONTINUE
496.000       IF(X - XPR+ DX/4.) 5,250,250
497.000  250  CONTINUE
498.000       XPR = XPR + DXPR
499.000       IF(X - XEND) 5,300,300
500.000 105   CONTINUE
501.000       JUMP = +1
```

```
502.000 110   CONTINUE
503.000       XPR = X + DXPR
504.000 120   CONTINUE
505.000       CALL SRD(YP,X,XPR,Y,ERROR,NE,Dx,DxMAX,JUMP,KSTP,KCON,CLIF,IO)
506.000       IF(JUMP)130,140,150
507.000 130   WRITE(IS,131) X
508.000 131   FORMAT(///'    X ='E14.5'  INTEGRATION FAILURE')
509.000       RETURN
510.000 140   CONTINUE
511.000       CALL DIFEQ
512.000       GO TO 120
513.000  150  CONTINUE
514.000       IF(X - XEND) 110,300,300
515.000  300  CONTINUE
516.000       RETURN
517.000       END
518.000 CCCCC
519.000 CCCCC
520.000 CCCCC
521.000 CCCCC
522.000       SUBROUTINE INPUT
523.000       DIMENSION PTBL(10),TTBL(10)
524.000       COMMON YP(5), DT,      DUM(4),XPR,XEND,DxPR,X,DX,NE,INT,INTC,
525.000      1 IN,IO,EL,AREA,U,ERROR,DXMAX,TEMP,HFGTB(10),CONS1
526.000       COMMON RHP,W,WMD,HD,TAIR,CLD,RH,ALBAR,TWS,TA,TWSA,EW,EA,HOS,HS
527.000       COMMON HSR,HOR,FBR,EVAP,HE,HC,HLYMN,PTBL ,TTBL ,WMS,CONST
528.000       COMMON CLIF,HFG,HBC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
529.000      1DTA,DW,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
```

```
530.000 10    FORMAT(4F10.0)
531.000 20    FORMAT(6I10)
532.000       RATIO = 3.14159/180.
533.000 C     NUMBER OF EQUATIONS AND CHOICE OF INTEGRATION SUBROUTINE
534.000       NE=1
535.000       INTC=1
536.000       IF(INTC - 3) 30,40,50
537.000 30    INT = INTC
538.000       GO TO 60
539.000 40    INT = 4
540.000       GO TO 60
541.000 50    CONTINUE
542.000 60    CONTINUE
543.000       JFLA=1
544.000       IF(JFLA-1)65,150,65
545.000    65 CONTINUE
546.000       GO TO (110,120,130,140), INTC
547.000 110   WRITE(IO,115)
548.000 115   FORMAT('1     ****   EULER INTEGRATION    *****'//)
549.000       GO TO 150
550.000 120   CONTINUE
551.000       WRITE(IO,125)
552.000 125   FORMAT('1     *****  MOD. EULER INTEGRATION  *****'//)
553.000       GO TO 150
554.000 130   WRITE(IO,135)
555.000 135   FORMAT('1     *****  4 TH ORDER  RUNGE-KUTTA  ******'//)
556.000       GO TO 150
557.000 140   WRITE(IO,145)
558.000 145   FORMAT('1     *****   ADAMS MOULTON INTEG.  *******'//)
```

```
559.000 150   CONTINUE
560.000 C
561.000 C     INTEGRATION CONTROL PARAMETERS
562.000       CONST = FL/(RHO*U*AREA)
563.000       CONS1 = (RHO*0.00328)/(24.**3600.**0.0614)
564.000       DTA = DTAIR*5./9.
565.000       HBS = 1.9*SIN(ALBAR*RATIO)
566.000       HBC = 1.9*COS(ALBAR*RATIO)
567.000       CLD1 = 1. - .0745*CLD
568.000       CLD2 = -.0018*CLD**2
569.000       CLD3 = 1. - .0006*CLD**3
570.000       DALPR = DALP * RATIO
571.000       DW = DWMPH*22./15.
572.000       DWMS = DW * .3048
573.000       DWMD = DWMPH*24.
574.000 C     INCIDENT SOLAR RADIATION
575.000       HS = HBS * CLD3
576.000 C     REFLECTED SOLAR RADIATION
577.000       HSR = HS * 3./ALBAR
578.000       FTA = SI(TTBL,PTBL,TAIR,10)
579.000       EA = RH*(1013./1470.)*FTA
580.000       TAIRP = TAIR+DTAIR
581.000       FTAP = SI(TTBL,PTBL,TAIRP,10)
582.000       DEA = (1013./1470.)*(DRH*FTA + RH*(FTAP - FTA))
583.000       IFLA=1
584.000       IF(IFLA-1) 198,199,198
585.000  198  CONTINUE
586.000       WRITE(10,200) DT
```

```
587.000 200   FORMAT('  INITIAL DT ='F12.4          '       DEG F'/)
585.000       WRITE(19,210) J,AREA,EL
589.000 210   FORMAT('  STREAM VELOCITY ='F6.3' FT/SEC   CR. SEC. AREA ='
590.000      1F10.2'  SQ. FT.      SURFACE WIDTH ='F6.1'  FT'/)
591.000       WRITE(19,220) RHB,CLD,RH,ALBAR
592.000 220   FORMAT('  RHB='F5.2'  LB/CU.FT.      CLD='F4.1'  TENTHS',
593.000      1'     RH='F5.1'  PCT'/'  ALBAR ='F4.1'  DEGREES'/)
594.000       WRITE(19,230) TAIR,TA,C8NST,C8NS1
595.000 230   FORMAT('  AIR TEMP. ='F5.1'  DEG F'F8.1'  DEG C',
596.000      1'     C8NST ='E10.3'    C8NS1 ='F10.3,/)
597.000       WRITE(19,240) W,WMPH,WMS,WMD
598.000 240   FORMAT('  WIND VELOCITY ='F6.2' FT/SEC'F8.2'MPH'F8.2' METERS',
599.000      1'/SEC'F8.2'  MILES/DAY'/)
600.000       WRITE(19,260)
601.000 260   FORMAT(/,T20'TTBL'T40'PTBL'T60'HFGTB'/)
602.000       DO 270 I =1,10
603.000 270   WRITE(19,280) TTBL(I), PTBL(I), HFGTB(I)
604.000 280   FORMAT(10X,3F20.5)
605.000       WRITE(19,300)DCLD,DRH,DTAIR
606.000 300   FORMAT(/'  DCLD ='F6.3'  DRH ='F5.3'  DTAIR ='F6.2)
607.000       WRITE(19,310) DALP,DWMPH
608.000 310   FORMAT(/'  DALP ='F6.2'  DWMPH ='F6.2)
609.000       WRITE(19,320) H9S,H9C,HS,HSR
610.000 320   FORMAT(/'  H9S='E12.4'  H9C='E12.4'  HS='E12.4'  HSR='E12.4' LY/MIN'
611.000      1N')
612.000       WRITE(19,330) EA,DEA
613.000 330   FORMAT(/'  EA ='E12.4'  DEA ='F12.4)
614.000       WRITE(19,340)
615.000 340   FORMAT(/,T20'STTBL'T40'XTBL'/)
```

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```
615.000  199  CONTINUE
617.000       RETURN
618.000       END
619.000 CCCCC
620.000 CCCCC
621.000 CCCCC
622.000 CCCCC
623.000       SUBROUTINE OUPT
624.000       COMMON  DDT,YP(4), DT,DUM(4),XPR,XEND,DXPR,X,DX,NE,INT,
625.000      1INTC, IN,IO,FL,AREA,J,ERROR,DXMAX,TEMP,HFGTB(10),CONS1
626.000       COMMON RHO,W,WMO,HO,TAIR,CLD,RH,ALBAR,TWS,TA,TWSA,EW,EA,HBS,HS
627.000       COMMON HSR,HBS,EBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CONST
628.000       COMMON CI IF,HFG,HAO,CLD1,CLD2,CLDR,DALP,DALPR,DCLD,DRH,DTAIR,
629.000      1DTA,DA,DWMS,DAMO,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
630.000       WRITE(IO,10) X,DX
631.000  10   FORMAT('     X ='F7.1' FT    DX ='F6.1        ,/)
632.000       WRITE(IO,20) TEMP
633.000  20   FORMAT('  STREAM TEMP ='E12.4' DEG F'/)
634.000       WRITE(IO,70) DT,DDT
635.000       WRITE(IO,30) EW,DEW,EVAP,HE,HFG
636.000  30   FORMAT('  EW ='F12.5'   DEW ='F12.5'  EVAP ='E12.5'   HE ='
637.000      1E12.5'  LY/MIN    HFG ='E12.5,/)
638.000       WRITE(IO,50) HBR,EBR,HC
639.000  50   FORMAT('  HBR ='E12.5'   EBR='F12.5'   HC  ='E12.5'  LY/MIN'/)
640.000       WRITE(IO,60) HLYMN,HO
641.000  60   FORMAT('  TOTAL HEAT TRANSFER ='F12.5'  LY/MIN'E15.5,
642.000      1'   BTU/SEC-FT2'/)
643.000  70   FORMAT('  DT ='F12.5'    DDT ='F12.5,/)
```

```
644.000         WRITE(19,80) DLYMN,DBTUS
645.000 80      FORMAT('  DLYMN ='E12.5'     DBTUS ='E12.5,/)
646.000         WRITE(19,90)
647.000 90      FORMAT(1X,60('*'),///)
648.000         RETURN
649.000         END
650.000 CCCCC
651.000 CCCCC
652.000 CCCCC
653.000 CCCCC
654.000         SUBROUTINE DIFEQ
655.000         COMMON  DDT,YP(4),  DT,            DUM(4),XPR,XEND,DXPR,X,DX,NE,
656.000        1INT,INTC,  IN,IS,EL,AREA,U,ERROR,DXMAX,TEMP,HFGTB(10),CONST
657.000         COMMON/RHB/W,WMD,HD,TAIR,C,RH,AIRBAR,TWS,TA,TWSA,EW,EA,HBS,HS
658.000         COMMON HSR,HBB,FBR,EVAP,HE,HC,HLYMN,PTBL(10),TTBL(10),WMS,CONST
659.000         COMMON CLIF,HFG,HRC,CLD1,CLD2,CLD3,DALP,DALPR,DCLD,DRH,DTAIR,
660.000        1DTA,DX,DWMS,DWMD,DEA,DEW,DLYMN,DBTUS,NTEMP,STTBL(10),XTBL(10)
661.000 C       THERMAL EXCHANGE WITH ENVIRONMENT.
662.000         TEMP = SI(XTBL,STTBL,X,NTEMP)
663.000         TWS= (TEMP-32.)*5./9.
664.000         TWSA = TWS + 273.
665.000         DTWS = DT*5./9.
666.000         FTA = SI(TTBL,PTBL,TEMP,10)
667.000         TTW = TEMP + DT
668.000         FTB = SI(TTBL,PTBL,TTW,10)
669.000         EW = (1013./14.7)*FTA
670.000         DEW = (1013./14.7)*(FTB - FTA)
671.000 C       EFFECTIVE BACK RADIATION.
672.000         HBB= (14.38-.09*TWS-.046*RH)/69.72
```

```
673.000         EBR = H9R*CLD1
674.000 C       EVAPORATION HEAT TRANSFER.
675.000         EVAP = .35* (EW-EA)*(1. + .009R* WMD)
676.000         HFG = SI(TTBL,HFGTR,TEMP,10)
677.000         HE = EVAP*HFG*CONS1
678.000 C       CONVECTION HEAT TRANSFER
679.000         HC = 39.*(.26 + .077*WMS)*(TWS - TA )/1440.
680.000 C       TOTAL HEAT TRANSFER TO WATER, LY/MIN
681.000         HLYMN = HS - (EBR + HSR + HC + HE)
682.000 C       TOTAL HEAT TRANSFER, BTU/SEC-FT2
683.000         HD = HLYMN * .0414
684.000         F1 = CLDR*DCLD*HBS
685.000         F2 = CLDR*HBC*DALPR
686.000         F3 = .0765*DCLD*HBR
687.000         F4 = -CLD1*(-.09*DTWS - .046*DRH)/59.72
688.000         F5 = -(F1+F2)*3./ALBAR
689.000         F6 = HS*3.*DALP/ALBAR**2
690.000         F7 = -(.35*HFG/1440.)*((1. + .009R*WMD)*(DEW - DEA) +
691.000        1 .0098*DW1D*(EW - EA))
692.000         F8 = -(39./1440.)*((.26 + .077*WMS)*(DTWS - DTA) +
693.000        1 .077*DWMS*(TWS - TA))
694.000         DLYMN = F1 + F2 + F3 + F4 + F5 + F6 + F7 + F8
695.000         DBTUS = DLYMN*.0614
696.000         DDT = CONST*DBTUS
697.000         RETURN
698.000         END
699.000 CCCCC
700.000 CCCCC
```

```
701.000 CCCCC
702.000 CCCCC
703.000       FUNCTION SI(XTBL,YTBL,X,N)
704.000 C     LINEAR INTERPOLATION OR EXTRAPOLATION OF SINGLE VARIABLE FUNCTION
705.000 C     XTBL = INDEPENDENT VARIABLE TABLE
706.000 C     YTBL = DEPENDENT VARIABLE TABLE
707.000 C     IND = INDICATOR OF EXTRAPOLATION
708.000 C     0=NO EXTRAPOLATION, 1=LOWER EXTRAPOLATION, 2=UPPER EXTRAPOLATION
709.000       DIMENSION XTBL(40),YTBL(40)
710.000 C     CHECK TO SEE IF EXTRAPOLATION IS NEEDED.
711.000       IF(X-XTBL(1)) 120,130,150
712.000   120 IND = 1
713.000   130 II = 2
714.000       GO TO 254
715.000   150 IF(XTBL(N)-X) 140,180,210
716.000   160   IND = 2
717.000   180   II = N
718.000       GO TO 254
719.000 C     FIND X IN TABLE.S IN TABLE
720.000   210 DO 220 IK=2,N
721.000       II = IK
722.000       IF(XTBL(IK)-X) 220,254,254
723.000   220 CONTINUE
724.000   254 X1 = XTBL(II-1)
725.000       X2 = XTBL(II)
726.000       Y1 = YTBL(II-1)
727.000       Y2 = YTBL(II)
728.000       SI = Y1+(Y2-Y1)*(X-X1)/(X2-X1)
729.000       RETURN
```

```
730.000       END
731.000 CCCCC
732.000 CCCCC
733.000 CCCCC
734.000 CCCCC
735.000       SUBROUTINE EULER(YP,Y,DT,NE,J,T)
736.000       DIMENSION YP(20),Y(20), SY(20),SYP(20)
737.000       GO TO(10,20),J
738.000    10 CONTINUE
739.000       DO 100 I=1,NE
740.000       SY(I)= Y(I)
741.000       SYP(I)= YP(I)
742.000       Y(I)= Y(I)+DT*YP(I)
743.000   100 CONTINUE
744.000       T=T+DT
745.000       RETURN
746.000    20 CONTINUE
747.000       DO 200 I=1,NE
748.000       Y(I)= SY(I)+(YP(I)+SYP(I))*DT/2.
749.000   200 CONTINUE
750.000       RETURN
751.000       END
752.000 CCCCC
753.000 CCCCC
754.000 CCCCC
755.000 CCCCC
756.000       SUBROUTINE RK4(YP,Y,DT,NE,J,T)
757.000       DIMENSION YP(5),Y(5),AK(5,4),SY(5)
```

```
      GO TO(10,20,30,40),J
10    CONTINUE
      DO 100 I=1,NE
      SY(I) = Y(I)
      AK(I,1) = DT*YP(I)
      Y(I) = Y(I) +AK(I,1)*.5
100   CONTINUE
      ST = T
      T = T + DT*.5
      RETURN
20    CONTINUE
      DO 200 I=1,NE
      AK(I,2) = DT*YP(I)
      Y(I) = SY(I) + AK(I,2)*.5
200   CONTINUE
      RETURN
30    CONTINUE
      DO 300 I = 1,NE
      AK(I,3) = DT*YP(I)
      Y(I) = SY (I) + AK(I,3)
300   CONTINUE
      T = ST + DT
      RETURN
40    CONTINUE
      DO 400 I = 1,NE
      AK(I,4) = DT *YP(I)
      Y(I)=SY(I)+(AK(I,1)+AK(I,4)+2.*(AK(I,2)+AK(I,3)))/6.
400   CONTINUE
      RETURN
```

```
787.000       END
788.000 CCCCC
789.000 CCCCC
790.000 CCCCC
791.000 CCCCC
792.000       SUBROUTINE SRD(F,T,TLIM,Y,ERRBR,NF,H,HMAX,JUMP,KSTP,KCON,CLIF,I8)
793.000       DIMENSION STARY(5),Y(5),SY(5),SAVFY(5),F(5),FP(5),DELTA(5),DALTA(5
794.000      1),A(5),B(5),C(5),D(5),AA(5),BB(5),CC(5),DD(5),SF(5)
795.000       IF(KSTP-32767)993,991,991
796.000   991 KSTP=28
797.000 C     TEST FOR TYPE OF ENTRY
798.000   993 IF(JUMP)1,998,999
799.000   998 GO TO (1000,11,21,802,803),IA
800.000 C     JUMP POS.     RESTORE VALUES
801.000   999 T=SAVET
802.000   992 JUMP=0
803.000       DO 901 I=1,NF
804.000       F(I)=SF(I)
805.000   901 Y(I)=SAVFY(I)
806.000       GO TO 100
807.000 C     JUMP NEG.     INITIALIZE
808.000     1 DO 5 I=1,NE
809.000       STARY(I)=Y(I)
810.000       A(I)=0.001
811.000       B(I)=0.001
812.000       C(I)=0.001
813.000     5 D(I)=0.001
814.000       KSTP=0
```

```
815.000        KDELY=0
816.000        KCBN=0
817.000        XT=95./(288.**64.)
818.000        U=863./(12.**5040.)
819.000        V=95.0/288.0
820.000        P=25.0/24.0
821.000        Q=35.0/72.0
822.000        R=5.0/48.0
823.000        S=1.0/120.0
824.000        IA=1
825.000        JUMP=0
826.000        GO TO 1101
827.000 C      BEGIN INTEGRATION STEP
828.000  1000  DO 1111 I=1,NE
829.000        SF(I)=F(I)
830.000  1111  SAVEY(I)=Y(I)
831.000 C      H TOO SMALL  RETURN WITH JUMP NEG.
832.000   600  IF(ABS(T+H)-ABS(T))605,601,605
833.000   601  JUMP=-1
834.000        GO TO 1101
835.000   605  T=T+H
836.000        DO 10 I=1,NE
837.000        Y(I)=Y(I)+H*(F(I)+A(I)+B(I)+C(I)+D(I))
838.000    10  FP(I)=F(I)+2.0*A(I)+3.0*B(I)+4.0*C(I)+5.0*D(I)
839.000        IA=2
840.000        GO TO 1101
841.000    11  DO 12 I=1,NE
842.000    12  SY(I)=Y(I)
843.000        DO 20 I=1,NE
```

```
844.000          DELTA  (I)=F(I)-FP(I)
845.000       20 Y(I)=Y(I)+V*DELTA  (I)*H
846.000          IA=3
847.000          KCBN=1
848.000          GO TO 1101
849.000       21 KCBN=0
850.000          DO 30 I=1,NE
851.000          DALTA  (I)=F(I)-FP(I)
852.000       29 Y(I)=SY(I)+V*DALTA  (I)*H
853.000       30 CONTINUE
854.000 C        TEST FOR STARTING SEQUENCE
855.000       31 IF(KSTP-28)35,40,40
856.000 C        APPLY TEST 2 ON ZEROTH STEP
857.000       35 IF(KSTP)50,50,60
858.000 C        HALVING TESTS
859.000       40 DO 45 I=1,NE
860.000          IF(ABS(DALTA  (I))-ERROR/ABS(H))45,45,55
861.000       45 CONTINUE
862.000       50 IF(V*H*C( IF-0.125)60,60,55
863.000       55 T=T-H
864.000 C        FAIL TESTS, HALVE H
865.000      223 H=H/2.0
866.000          KDELY=0
867.000          DO 56 I=1,NE
868.000          A(I)=A(I)/2.0
869.000          B(I)=B(I)/4.0
870.000          C(I)=C(I)/8.0
871.000          F(I)=SF(I)
```

```
872.000          Y(I)=SAVEY(I)
873.000       56 D(I)=D(I)/16.0
874.000          GO TO 1000
875.000 C        PASS TESTS, CORRECT A,B,C,D
876.000       60 KSTP=KSTP+1
877.000          DO 65 I=1,NE
878.000          A(I)=A(I)+3.0*B(I)+6.0*C(I)+10.0*D(I)+P*DALTA  (I)
879.000       62 B(I)=B(I)+4.0*C(I)+10.0*D(I)+Q*DALTA(I)
880.000       64 C(I)=C(I)+5.0*D(I)+R*DALTA(I)
881.000       67 D(I)=D(I)+S*DALTA(I)
882.000       65 CONTINUE
883.000 C        IF IN STARTING SEQUENCE, BRANCH
884.000          IF(KSTP-24)70,90,100
885.000       70 GO TO (1000,1000,1000,74,1000,1000,1000,78,1000,1000,1000,74,1000,
886.000         1 1000,1000,86,1000,1000,1000,74,1000,1000,1000),KSTP
887.000 C        4TH, 12TH, 20TH STEP, GO BACK
888.000       74 H=-H
889.000          DO 75 I=1,NE
890.000          A(I)=-A(I)
891.000       75 C(I)=-C(I)
892.000          GO TO 1000
893.000 C        8TH STEP  GO FORWARD
894.000       78 H=-H
895.000          DO 79 I=1,NE
896.000          Y(I)=STARY(I)
897.000          A(I)=-A(I)
898.000       79 C(I)=-C(I)
899.000          GO TO 1000
900.000 C        16TH STEP, HALVE H, APPLY TEST 1
```

```
901.000     86 H=H/2.0
902.000        DO 87 I=1,NE
903.000        A(I)=A(I)/2.0
904.000        B(I)=B(I)/4.0
905.000        C(I)=C(I)/8.0
906.000     87 D(I)=D(I)/16.0
907.000        DO 88 I=1,NE
908.000        IF(ABS(DELTA  (I))-ERROR/ABS(H))88,88,89
909.000     88 CONTINUE
910.000 C      PASS TEST   GO FORWARD WITH HALVED H
911.000        GO TO 78
912.000 C      FAIL TEST   BEGIN AGAIN WITH HALVED H
913.000     89 H=-H
914.000        DO 92 I=1,NE
915.000     92 Y(I)=STARY(I)
916.000        GO TO 1
917.000 C      2.TH STEP, DOUBLE H, STARTING SEQUENCE ENDS
916.000     90 H=H+2.0
919.000        DO 91 I=1,NE
920.000        A(I)=A(I)+2.0
921.000        B(I)=B(I)+4.0
922.000        C(I)=C(I)+8.0
923.000     91 D(I)=D(I)+16.0
924.000        GO TO 78
925.000    100 KDELY=KDELY+1
926.000 C      WILL NEXT STEP MOVE PAST TLIM
927.000    102 IF(ABS(TLIM-T)-ABS(H))103,103,110
928.000 C      YES.........SAVE T AND Y, INTEGRATE TO TLIM,RETURN.
```

```
929.000    103 ENDH=TLIM-T
930.000        DO 105 I=1,NF
931.000        AA(I)=ENDH*A(I)/H
932.000        BB(I)=ENDH**2*B(I)/H**2
933.000        CC(I)=ENDH**3*C(I)/H**3
934.000    105 DD(I)=ENDH**4*D(I)/H**4
935.000        SAVET=T
936.000        DO 800 I=1,NF
937.000        SF(I)=F(I)
938.000    800 SAVEY(I)=Y(I)
939.000    806 T=TLIM
940.000        DO 106 I=1,NF
941.000        Y(I)=Y(I)+ENDH*(F(I)+AA(I)+BB(I)+CC(I)+DD(I))
942.000    106 FP(I)=F(I)+2.0*AA(I)+3.0*BB(I)+4.0*CC(I)+5.0*DD(I)
943.000        IA=4
944.000        GO TO 1101
945.000    802 DO 805 I=1,NF
946.000    805 SY(I)=Y(I)
947.000        DO 107 I=1,NF
948.000        DELTA  (I)=F(I)-FP(I)
949.000    107 Y(I)=Y(I)+V*DELTA  (I)*FNDH
950.000        IA=5
951.000        GO TO 1101
952.000    803 DO 108 I=1,NF
953.000        DALTA  (I)=F(I)-FP(I)
954.000    108 Y(I)=SY(I)+V*DALTA  (I)*ENDH
955.000        JJMP=1
956.000        GO TO 1101
957.000 C      NO.......TEST FOR DOUBLING. IF OK, BEGIN NEST STEP AFTER DOUBLING
```

```
958.000    110 IF(ABS(TIM-T)-ABS(2.0*H))1000,1000,111
959.000    111 IF(KDELY-4)1000,120,120
960.000    120 IF(ABS(2.0*H)-ABS(HMAX))121,121,1000
961.000    121 DO 125 I=1,NF
962.000        IF(ABS(DALTA  (I))-ERROR/(128.0*ABS(H)))125,125,1000
963.000    125 CONTINUE
964.000        IF(V.H.CL IF-0.0625)130,1000,1000
965.000    130 CONTINUE
966.000    335 H=2.0*H
967.000        DO 135 I=1,NF
968.000        A(I)=2.0*A(I)
969.000        B(I)=4.0*B(I)
970.000        C(I)=8.0*C(I)
971.000    135 D(I)=16.0*D(I)
972.000        KDELY=0
973.000        GO TO 1000
974.000   1101 CONTINUE
975.000   1150 FORMAT(/,2X,'HH =',2X,F10.6,14X,'KSTP =',2X,I3,10X,'DALTA(I)',/)
976.000   1151 FORMAT(5(2X,I2,1X,E14.7))
977.000        RETURN
978.000        END
979.000 CCCCC
980.000 CCCCC
981.000 CCCCC
982.000 CCCCC
983.000 CCCCC
984.000        SUBROUTINE DEBUG(A,N)
985.000        I90=102
```

```
      WRITE(I9U,1000)A,N
1000 F9RMAT(1H9,2X,'A=',E14.7,1X,'N=',I4)
      RETURN
      END
      SUBR9UTINE PR9U
      C9MM9N YP1(5),Y1(5),XPR1,XEND1,DXPR1,X1,DX1,NE1,INT1,INTC1,IN1,I01
     1,EL1,ARFA1,U1
      C9MM9N ERR9R1,DXMAX1,TEMP1,HFGT31(10),C9NS11
      C9MM9N RH91,W1,WMD1,WD1,TAIR1,CLD1,RH1,ALBAR1,TWS1,TA1,TWSA1,EW1,
     1EA1,H0S1,HS1
      C9MM9N HSR1,H9B1,ERR1,EVAP1,HE1,HC1,HLYMN1,PTBL1(10),TTBL1(10),
     1W1S1,C9NST1
      C9MM9N CLIF1,HF31,H3C1,CLD11,CLDP1,CLDB1,DALP1,DALPR1,DCLD1,DRH1,
     1DTAIR1,DTA1,DW1,DWMS1,DWMD1,DEA1,DEW1,DLYMN1,DBTUS1,NTEMP1,
     2STTBL1(10),XTBL1(10)
      C9MM9N C(1000),TA(1000),PHI(1000),W(1000),TW(1000)
      C9MM9N NCAS, NDA, DELT(50), IDAS(50)
      C9MM9N NIN,IN,I9J,DT,NTA,IDA
      C9MM9N CTA(50),TATA(50),PHITA(50),WTA(50),TWTA(50)
      C9MM9N UA,EL,CC,TAIR,TWA,RH,WSP
      C9MM9N INT2,INT3,DC,DTA,DPHI,DW,DTW,INVS,IFLAG
      C9MM9N DM21,BETA
      C9MM9N LAG1,NDAS
      C9MM9N IDAS,PRP(50,10)
      WRITE(I9U,2000)
2000 F9RMAT(1H0,2X,'PR9BABILITY CHART'/,2X,60('*'))
      WRITE(I9U,2001)(DELT(I),I=1,NCAS)
2001 F9RMAT(1H0,10X,10(E10.3,1X))
      D9 10 I=1,NDAS
```

```
1015.000       WRITE(IS0,2002)IDAS(I),(PRP(I,J),J=1,NCAS)
1016.000  2002 FORMAT(1H0,2X,I5,1X,5(E10.3,1X))
1017.000    10 CONTINUE
1018.000       RETURN
1019.000       END
1500.000       SUBROUTINE VERNON
1501.000       COMMON YP1(5),Y1(5),XPR1,XEND1,DXPR1,X1,DX1,NE1,INT1,INTC1,IN1,IB1
1502.000      1,EL1,AREA1,U1
1503.000       COMMON ERR1,DXMAX1,TEMP1,HF3TR1(10),CONST1
1504.000       COMMON RH81,W1,WMD1,HD1,TAIR1,CLD1,RH1,ALBAR1,TWS1,TA1,TWSA1,EW1,
1505.000      1EA1,HBS1,HS1
1506.000       COMMON HSR1,H8B1,ERR1,EWAP1,HF1,HC1,HLYMN1,PTBL1(10),TTBL1(10),
1507.000      1WMS1,CONST1
1508.000       COMMON CLIF1,HF31,H8C1,CLD11,CLD21,CLD31,DALP1,DALPR1,DCLD1,DRH1,
1509.000      1DTAIR1,DTA1,DN1,DWMS1,DWMD1,DEA1,DEW1,DLYMN1,DBTUS1,NTEMP1,
1510.000      2STTBL1(10),XTBL1(10)
1511.000       COMMON C(1000),TA(1000),PHI(1000),W(1000),TW(1000)
1512.000       COMMON NCAS, NDA, DELT(50), IDAS(50)
1513.000       COMMON MIN,IN,IBD,DT,NTA,IDA
1514.000       COMMON CTA(50),TATA(50),PHITA(50),WTA(50),TWTA(50)
1515.000       COMMON GA,EL,CC,TAIR,TWA,RH,WSP
1516.000       COMMON INT2,INT3,DC,DTA,DPHI,DW,DTW,INVS,IFLAG
1517.000       COMMON DM21,RETA
1518.000       COMMON LAG1,NDAS
1519.000       COMMON IDAS,PRP(50,10)
1520.000       DIMENSION PR(10),T7(100)
1520.010       DO 3 I=1,NCAS
1520.020       PR(I)=0.
```

```
1520.030      3  CONTINUE
1521.000 C       NDA= NUMBER OF DAYS IN THE CASE
1522.000         NDA=1
1523.000         NC1=N_N/8
1524.000         FNDA=NDA*8
1525.000         FNDA=1./FNDA
1526.000         READ(IN,1020)(T7(I),I=1,NC1)
1527.000  1020 FORMAT(8F10.3)
1528.000         DO 5 I=1,NC1
1526.010         WRITE(IPU,2001)T7(I)
1528.020  2001 FORMAT(/,2X,F14.7)
1528.030      5 CONTINUE
1532.000         IF(NDA-NC1) 10,999,999
1532.500     10  CONTINUE
1533.000         NDIF=NC1-NDA
1534.000         ENUM=0.
1535.000         DEN=0.
1536.000         DEN2=0.
1537.000         DO 20 I20=1,NDIF
1538.000         CS=0.
1539.000         TAS=0.
1540.000         PHIS=0.
1541.000         WS=0.
1542.000         TWS=0.
1543.000         DO 30 I=1,NDA
1544.000         DO 40 J=1,8
1545.000         INT=8*(I20+I-1)+J-8
1546.000         CS=CS + C(INT)
1547.000         TAS=TAS + TA(INT)
```

```
      PHIS=PHIS + PHI(INT)
      WS=WS + W(INT)
   40 CONTINUE
   30 CONTINUE
      CS= CS*FNDA
      TAS= TAS*FNDA
      PHIS=PHIS*FNDA
      WS= WS*FNDA
      TWS=T7(I20)
C     INT2= FOLLOWING DAY
      INT2= I20+NDA
      C1S=0.
      TA1S=0.
      PHI1S=0.
      W1S=0.
      TW1S=0.
      DO 50 I=1,8
C     INT3= THE ACTUAL POSITION IN THE DAY
      INT3=INT2*8-8+I
      C1S=C1S+C(INT3)
      TA1S=TA1S+TA(INT3)
      PHI1S=PHI1S+PHI(INT3)
      W1S=W1S+W(INT3)
      TW1S=TW1S+TW(INT3)
   50 CONTINUE
      C1S=C1S*.125
      TA1S=TA1S*.125
      PHI1S=PHI1S*.125
```

```
1577.000          W1S=W1S+.125
1578.000          TW1S=TW1S+.125
1579.000          DC=C1S-CS
1580.000          DTA=TA1S-TAS
1581.000          DPHI=PHI1S-PHIS
1582.000          DW=W1S-WS
1583.000          DTW=TW1S-TWS
1584.000          STTBL1(1)=TW1S
1585.000          STTBL1(2)=TW1S
1586.000          XTBL1(1)=0.
1587.000          XTBL1(2)=25000.
1588.000          NTEMP1=2
1589.000          INVS=INT2*8-4
1590.000          CALL COMP(ENUM,DEN)
1591.000          DO 60 ICAS=1,NCAS
1592.000          IF(ABS(Y1(1))-DELT(ICAS)) 65,65,70
1593.000    65    CONTINUE
1594.000          PR(ICAS)=PR(ICAS)+1.
1595.000    70    CONTINUE
1596.000    60    CONTINUE
1597.000    80    CONTINUE
1598.000          DENP=NDIF
1599.000          DO 75 ICAS=1,NCAS
1600.000          PR(ICAS)=PR(ICAS)/DENP
1601.000    75    CONTINUE
1601.010          WRITE(IRU,2000)(PR(I),I=1,NCAS)
1601.020  2000 FORMAT(/,2X,'STATION 7 RESULTS',10(F6.3,1X))
1601.025          RETURN
1601.030    999   CONTINUE
1601.040          WRITE(IRU,4000)
1601.050  4000 FORMAT(/,2X,'T89 SMALL')
1601.060          CALL EXIT
1602.000          RETURN
1603.000          END
```

APPENDIX D

THEORY OF THE SENSITIVITY ANALYSIS

In this appendix the development of the equation (1) is discussed together with the problems of convergence and averaging of the data. The sensitivity analysis is further discussed with the exact solution being developed for the constant coefficient equation.

THE GENERAL STREAM MODEL

The equation (1) is developed from the energy equation heat fluxes shown in Figure 1. The development of this equation is based on a Taylor's expansion of the dependent variable, T, about the position, x, downstream:

$$T(x + dx) = T(x) + \frac{dT}{dx}(x)\, dx \quad . \qquad \text{(D-1)}$$

Use of this Taylor's expansion together with the conservation of energy for the control volume in Figure 1 yields:

$$uA\, T(x) - uA \left[T(x) + \frac{dT}{dx}(x)\, dx\right] +$$

$$+ \ell\, dx \left[Q_{Rad} - Q_{Ref} - Q_{Back} - Q_{Evap} + Q_{Conv} + Q_{Misc}\right] = 0 \quad . \qquad \text{(D-2)}$$

The first term is the enthalpy transport into the control volume; the second term is the analogous transport out of the control volume; the third term is the total heat flux at the air/water interface. Some minor algebra on equation (D-2) yields equation (1), assuming that the quantities u, A, and ℓ vary slowly along the stream.

The equation (1) holds between points at which flows and/or heated effluents are added to the stream. Many authors directly integrate equation (1) over a station length, Δx, assuming the fluxes and u, A, ℓ to be constant over that distance. The result is simply

$$\int_{x}^{x+\Delta x} \frac{uA}{\ell} \frac{dT}{dx}\, dx = \int_{x}^{x+\Delta x} \left[Q_{Rad} - Q_{Ref} - Q_{Back} + Q_{Evap}\right.$$

$$\left. + Q_{Conv} + Q_{Misc}\right] dx \quad ,$$

$$\frac{uA}{\ell}\,[T(x + \Delta x) - T(x)] = [Q_{Rad} - Q_{Ref} - Q_{Back} - Q_{Evap} + Q_{Conv} + Q_{Misc}]\,\Delta x \quad ,$$

$$T(x + \Delta x) = T(x) + \frac{\ell}{uA}\,[Q_{Rad} - Q_{Ref} - Q_{Back} - Q_{Evap} + Q_{Conv} + Q_{Misc}]\,\Delta x \quad . \qquad \text{(D-3)}$$

It is possible to then incorporate heat fluxes not covered by those at the air/water interface in the Q_{Misc} term, simplifying the coding and the model considerably. Two aspects of this concept should be emphasized: 1) all models are similar to this model and are within a small error that is a function of the mesh size, and 2) the convergence of the procedure can be shown from previous literature.

Suppose that an alternate model is used in which the fluxes are redistributed, i.e., the total flux may be the same but the model assumptions causes a difference in the flux at any position x. Then this difference can be represented as a quantity proportional to the station length, Δx. For example:

$$Q_{Rad}(x + \Delta x) = Q_{Rad}(x) + O(\Delta x) \quad . \qquad \text{(D-4)}$$

But the introduction of this expression into equation (D-3) will introduce a term of order Δx^2 ($O(\Delta x^2)$), which can be made appropriately small by a suitable choice of Δx. Thus, all correctly formulated models will be a measurable error away from the general model described by equation (1).

The question of numerical convergence of the solution is discussed in general by Salvadori and Baron [1961], p. 116. Much of the information provided by them can be directly applied to this problem.

Suppose a general problem takes the form

$$\dot{y} = f(x, y) \quad ,$$

$$y(0) = y_0 \quad . \qquad \text{(D-5)}$$

If Euler's method is taken as an example the form for the integration is

$$y_{i+1} = y_i + f(x_i , y_i)h \quad , \qquad \text{(D-6)}$$

which is seen to be identical in form to equation (D-3). From p. 91 in Salvadori and Baron

$$y(x) = \int_a^x f(z)\, dz \quad ,$$

$$\dot{y}(x) = f(x) \quad ,$$

$$\ddot{y}(x) = \dot{f}(x) \quad ,$$

$$y^{(n)}(x) = f^{(n-1)}(x) \quad . \qquad \text{(D-7)}$$

A Taylor's expansion about x yields:

$$y(x\pm h) = y(x) \pm \frac{h}{1!}f(x) + \frac{h^2}{2!}\dot{f}(x) \pm \frac{h^3}{3!}\ddot{f}(x) + \cdots \quad . \qquad \text{(D-8)}$$

From this the following expressions can be evaluated

$$I_1 = \int_x^{x+h} f(z)\, dz = y(x+h) - y(x) \quad ,$$

$$= h\left[f(x) + \frac{h}{2!}\dot{f}(x) + \frac{h^3}{3!}\ddot{f}(x) + \cdots\right] \quad , \qquad \text{(D-9)}$$

and

$$I_2 = \int_{x-h}^{x+h} f(z)\,dz = y(x+h) - y(x-h) \quad ,$$

$$= \left[2\,hf(x) + \frac{2h^3}{3!} f(x) + \frac{2h^5}{5!} f^{(IV)}(x) + \text{---}\right] \quad . \tag{D-10}$$

From Taylor's theorem and equation (D-6)

$$y(x+h) = y(x) + hf(x) + \frac{h^2}{2!} \dot{f}(\hat{x}) \tag{D-11}$$

and the error is proportional to the maximum value of the second derivative. With these fundamentals set down the error for the equation

$$\frac{dT}{dx} = \frac{Q\ell}{uA\rho c} \tag{D-12}$$

can be readily found. From the general analysis the error is bounded by the expression

$$\left|T_{Approximate} - T_{Exact}\right| \leq \frac{x\ell}{uA\rho c} \left|\frac{dQ}{dx}\right|_{max} \Delta x \quad . \tag{D-13}$$

An expression similar to (D-13) is easily developed for bounding the station length

$$\Delta x \leq \frac{\left|\Delta T_{allowable}\right|}{\frac{x_{max}\,\ell}{uA\rho c} \left|\frac{dQ}{dx}\right|_{max}} \quad . \tag{D-14}$$

From experience, a convergent Δx can easily be obtained for this differential equation since the heat fluxes are generally very small and have small derivaties.

DATA AVERAGING

For small changes in temperature the equation (1) will be quasi-linear. Thus, the theory of linear equations can be applied to the problem. This is very important since average data will produce average output to such a model, while a nonlinear model will not yield results of this type.

To prove this it is necessary to examine the theory from a different viewpoint. For example, the temperature at any point x downstream from the disturbance can always be represented from the linear equation in the form

$$T(x) = \sum_i \int_0^x K_i(x, \xi)\, Q_i(\xi)\, d\xi \qquad \text{(D-15)}$$

where the integral occurs over the domain of interest and the kernel function $K_i(x, \xi)$ relates the effect of the i'th heat flux $Q_i(\xi)$ at the position ξ to the temperature $T(x)$ at the position x ; the sum produces the effects of all of the heat fluxes. Since the expression is linear , it can be summed over several sets of heat fluxes to obtain the sum of temperatures as follows

$$\sum_j^n T_j(x) = \sum_i \sum_j^n \int_0^x K_i(x, \xi)\, Q_{ij}(\xi)\, d\xi \quad . \qquad \text{(D-16)}$$

Suppose that equation (D-16) is rearranged and both sides of the equation divided by the number of temperatures n :

$$\frac{1}{n} \sum_j^n T_j(x) = \sum_i \int_0^x K_i(x, \xi) \sum_j^n \frac{Q_{ij}}{n}(\xi)\, d\xi \quad . \qquad \text{(D-17)}$$

This proves that the effects of the heat fluxes can be averaged and the equation used to compute an average temperature. This would not be true for a nonlinear equation and is a significant result.

THE SENSITIVITY ANALYSIS

The fundamental equation for the sensitivity analysis is developed by varying both sides of the solution equation (1):

$$\frac{d\delta T}{dx} = \frac{\ell}{Au}\,\delta Q \quad , \tag{D-18}$$

where δQ is the change in the heat fluxes and δT the resulting change in the stream temperature. The initial condition for the equation is

$$\delta T(0) = \delta T_0 \quad , \tag{D-19}$$

i.e., an initial error in temperature δT_0 is known at a point in the stream, which allows the computation of the error at points downstream.

On closer examination of δQ the linearity of the solution emerges. The individual terms are

$$\delta Q_{Solar} = 1.9 \sin \bar{\alpha}\,(-0.0018\, C^2\, \delta C)(0.61) + (1.0 - 0.0006\, C^3)(1.9 \cos \bar{\alpha}\ \delta\bar{\alpha})(0.061) \quad ,$$

$$\delta Q_{Reflected} = \frac{3}{\bar{\alpha}}\,\delta Q_{Solar}(0.061) - \frac{6}{\bar{\alpha}^2}\,Q_{Solar}\ \delta\bar{\alpha}\,(0.061) \quad ,$$

$$\delta Q_{Back} = (1.0 - 0.0765\, C)\left(\frac{1}{69.72}\right)\left(-0.09\left(\frac{5}{9}\,\delta T\right) - 0.046\,\delta\phi\right) - 0.0765\,\delta C\left(\frac{1}{69.72}\right)\left(14.38 - 0.09\left(\frac{5}{9}(T - 32)\right) - 0.046\,\phi\right) \quad ,$$

$$\delta Q_{Evaporation} = \frac{\partial h_{fg}}{240} (0.35)(1.0 + 9.8 \times 10^{-3} W_2)(\delta e_W - \delta e_a)$$

$$+ \frac{\partial h_{fg}}{240} (0.35)(9.8 \times 10^{-3} \delta W_2)(e_W - e_a) \quad ,$$

$$\delta Q_{Convection} = 39.0 \ (0.077 \ \delta W_2)(T - T_a)(\tfrac{5}{9})(0.061)$$

$$+ 39.0 \ (0.26 + 0.077 \ W_2)(\delta T - \delta T_a)(\tfrac{5}{9})(0.061) \quad . \qquad \text{(D-20)}$$

Note that small changes in the heat fluxes imply like changes in δT. Thus, the justification in linearizing the analysis. The equation (D-18) is solved in this investigation using numerical analysis procedures. However, for constant coefficients in equation (D-18), the equation can be solved in closed form. Symbolically the equation can be written as:

$$\frac{d\delta T}{dx} = \frac{\ell}{\bar{A}u} [-C_1 \ \delta T + C_2 + C_3 + \text{---} \ C_m] \quad , \qquad \text{(D-21)}$$

where the C_i are constants. The solution to this equation is found in two parts, a homogeneous solution decaying with distance and particular solutions that are constant. The homogeneous solution is found by assuming it in the form

$$\delta T = \bar{A} \ e^{-\alpha x} \quad , \qquad \text{(D-22)}$$

where $\bar{A}$ is an initial amplitude and α is the decay rate. Substitution into equation (D-21) yields

$$-(\alpha) \ \bar{A} \ e^{-\alpha x} = \frac{\ell}{\bar{A}u} [- C_1 \ \bar{A} \ e^{-\alpha x}] \quad , \qquad \text{(D-23)}$$

which finds α to be

$$\alpha = \frac{\ell}{\bar{A}u} C_1 \quad . \qquad \text{(D-24)}$$

The particular solutions are found from

$$\delta T_i = \frac{C_i}{C_1} \quad , \qquad \text{(D-25)}$$

where $i = 2, ---, m$. It is on this basis that the sensitivity analysis is completed.